FISHERY MANAGEMENT INVESTIGATIONS

IDAHO DEPARTMENT OF FISH AND GAME
FISHERIES MANAGEMENT ANNUAL REPORT

Ed Schriever, Director

UPPER SNAKE REGION
2018

John Heckel, Regional Fisheries Biologist
Jenn Vincent, Regional Fisheries Biologist
Jon Flinders, Regional Fishery Biologist
Brett High, Regional Fisheries Manager

February 2022
IDFG 21-102

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPEDICIES

SOUTH FORK SNAKE RIVER

ABSTRACT

The South Fork Snake River supports the largest fluvial population of native Yellowstone Cutthroat Trout *Ocorhynchus clarkii bouvieri* (YCT) in Idaho. The South Fork also supports populations of Rainbow Trout *O. mykiss* (RBT) and Brown Trout *Salmo trutta* (BNT). Currently, populations (± 95% CI) of both RBT and YCT are stable with an estimated 1,137 YCT/km (± 70) and 1,907 RBT/km (± 249) at Conant, 1,064 YCT/km (± 269), and 1,386 (± 348) RBT/km at Lufkin, and 286 YCT/km (± 769) and 78 RBT/km at Lorenzo. Brown Trout abundance has shown stable trends at Lorenzo and Lufkin, and increasing trends at Conant. We estimated there were 653 BNT/km (± 124) at Lorenzo, 814 BNT/km (± 154) at Lufkin, and 836 BNT/km (± 129) at Conant. Relative weights were similar among monitoring reaches and were 95 for YCT, 97 for RBT, and 92 for BNT at Conant. We operated weirs on spawning tributaries with high efficiency, including 94% at Pine Creek. Higher spring runoff in spawning tributaries correlated with increasing age-1 YCT abundance the following year, but no correlation was present for age-1 RBT. The Angler Incentive Program (AIP continued with 3,205 harvested RBT turned in, including 102 tagged fish worth $9,150). We used randomized drainage-wide electrofishing to estimate YCT abundance in Palisades Creek and did not observe expansion of RBT distribution. We estimated there were 6,582 YCT >100 mm (± 3,293). We stocked 42,900 eyed YCT eggs from wild South Fork Snake River stock into lower Rainey Creek and estimated the proportion of fry production they comprised. We repeatedly removed RBT using electrofishing from a spawning redd complex and caught an average of 19 fish each time. Catch rates did not decline with weekly electrofishing passes until spawning concluded. We completed a habitat restoration project on Third Creek, tributary of Rainey Creek. The restored creek offers improved spawning and rearing habitat for YCT. We evaluated angler use and exploitation of Brown Trout in Warm Springs Creek and documented annual exploitation was low at 6%. Threats to YCT populations remain in the South Fork Snake River, but consistent and adaptive management can help maintain a viable YCT population.

Author:

Brett High
Regional Fisheries Biologist

INTRODUCTION

The South Fork Snake River (South Fork) in Eastern Idaho supports a robust population of wild trout including an important population of native Yellowstone Cutthroat Trout *Ocorhynchus clarkii bouvieri* (YCT). Other trout present in the South Fork include Rainbow Trout *O. mykiss* and Rainbow x Cutthroat Trout hybrids (RBT), Brown Trout *Salmo trutta* (BNT), and Mountain whitefish *Prosopium williamsoni* (MWF). Since 2004, a three-pronged management approach is used to accomplish the objectives outlined in the state fisheries management plan (IDFG 2013). This approach includes preserving the genetic integrity and population viability of native YCT and limiting RBT to less than 10% of the species composition of the catch at the Conant monitoring reach during annual fall electrofishing surveys. This report summarizes management and research activities on the South Fork in 2018. A broader description of the South Fork and additional background information is provided in Schoby et al. (2013).

In 2018, we continued to collect basic fish species distribution and abundance data in South Fork tributary drainages. This year, we focused efforts in the Palisades Creek drainage. Palisades Creek is one of the four main spawning tributaries for YCT in the South Fork network, and has some unique attributes. It is the only drainage in the South Fork that includes fish-bearing alpine lakes (Upper and Lower Palisades lakes). Also, RBT have established a population in Palisades Creek, but their distribution has been limited to downstream of a steep cascade immediately downstream of Lower Palisades Lake. A few sites have previously been surveyed in the Palisades Creek drainage, so our goal was to incorporate these historical sites to obtain trend data, and sample enough of the drainage to describe fish distribution and abundance.

We continued efforts in 2018 to bolster fluvial YCT numbers in Rainey Creek, another important South Fork tributary. Despite having the largest drainage area, Rainey Creek has had the smallest YCT spawning runs for the entire time weirs have been operated on the South Fork (since 2001). In 2017, IDFG initiated a project using wild-origin eyed-eggs stocked in Rainey Creek to try to increase fluvial spawning runs. This is the second year of this project which is anticipated to require five to seven years to evaluate.

In addition to the monitoring and research efforts described in Schoby et al. (2013), we also evaluated the effect of repeated electrofishing removals on South Fork RBT redds when RBT were removed from redds on a twice-a-week basis through the duration of the spawning season. As explained above, the fisheries management plan directs IDFG to protect native YCT by reducing RBT abundance at the Conant monitoring site to 10% or less of the species composition. To date, this objective has not been achieved. However, staff have improved the efficiency of removals using a three-pronged management approach including the South Fork Angler Incentive Program (AIP). The AIP offers a monetary incentive for anglers to harvest RBT by having marked fish in the South Fork with coded wire tags representing reward values ranging from $50 to $1,000 (Flinders et al. 2016). Continued investigation of techniques to more efficiently reduce RBT abundance in the South Fork is a priority. Manual suppression has been a successful tool for significantly reducing introgression rates in Palisades Creek, an important spawning tributary of the South Fork (Meyer et al. 2017), and may be a viable option for the South Fork. In order for this type of success to be possible in the main river, electrofishing efforts would have to be efficient at catching large numbers of RBT. The spawning season, when RBT congregate in shallow habitats, may be the season when they are most vulnerable to electrofishing. However, despite knowing where a handful of spawning locations are, it is clear that single-pass removals over these areas would not yield large enough catches to realize population-level impacts. Thus, we wanted to answer two questions during this 2018 redd electrofishing experiment: 1) Does catch decline with repeated electrofishing removals from a redd complex during the spawning season?

and 2) How long is the spawning season when RBT are congregated on redds? Answering these questions was the first step in determining the validity of using manual suppression as a tool to affect trout composition numbers in the South Fork.

Creel surveys are conducted routinely on the South Fork to pair fishery performance information in terms of angler effort, angler harvest, and catch rate information with population data gathered annually. Creel survey frequency has varied on the South Fork, but the current creel survey interval is five years. Creel survey durations have also varied as fishing seasons and regulations have changed. Current fishing regulations allow for fishing year round on the South Fork, so modern creel surveys also are conducted all year to capture effort, catch, and harvest statistics that vary seasonally.

Rainey Creek is one of the four main spawning tributaries in the South Fork and has the largest drainage area of all four tributaries, yet has the smallest adult YCT spawning run size. Adjacent spawning tributaries experience YCT escapement at a higher order of magnitude than Rainey Creek, which has consistently experienced less than 100 YCT adult migrants each spawning season since 2001, except for one year. While escapement in adjacent spawning tributaries is synchronous with cycles of abundance of YCT in the main river, escapement of YCT at Rainey Creek does not follow this trend. Habitat conditions in lower Rainey Creek have been affected by development, grazing, and agriculture, and do not support densities of trout observed higher in the drainage. However, habitat conditions in the middle and headwater portions of Rainey Creek on US Forest Service property are in good condition and support stable and healthy populations of resident YCT. Fluvial YCT appear to have access to these habitats as YCT marked with telemetry tags have been observed migrating from the South Fork to the forest boundary (IDFG unpublished data). With habitats that support healthy resident populations that are accessible to fluvial YCT, Rainey Creek may have experienced a population bottleneck with low numbers of fluvial fish, such that this life form is not making a quick recovery because of very low abundance. Therefore, we are experimenting with augmenting YCT abundance in Rainey Creek with eyed-eggs produced from wild YCT captured in the main South Fork near the creek's mouth. Our hope is that these eye-egg plants will bolster migratory YCT numbers in Rainey Creek and help that spawning run recovery more quickly.

In 2018, IDFG was able to implement a stream habitat restoration project on Third Creek, a tributary to lower Rainey Creek. Third Creek was likely a productive stream providing historic spawning and rearing habitat for YCT in Rainey Creek. The Rainey Creek drainage has been significantly degraded through anthropogenic activities including grazing, dewatering, straightening and berming to prevent flooding, for road construction, and other reasons. Habitat restoration goals include increasing complexity with wood addition and channel realignment to improve the availability of spawning and rearing habitat. The goal of our 2018 project on Third Creek was to restore natural stream function and aquatic habitat. The main habitat issue we wanted to address was water temperature, as we measured summer temperatures in excess of 23 ˚C during the summer of 2017. The existing habitat of Third Creek was an over-widened channel, which allowed increased solar input on a stream with reduced velocities. Additionally, an impoundment was created when an undersized culvert was used to make a road crossing of the creek, which also contributed to elevated water temperatures. Thus, our project involved replacing the undersized culvert with an over-sized squash pipe, decreasing channel widths appropriately, increasing sinuosity to provide habitat complexity, and planting riparian vegetation to increase shade. We will describe this 2018 project as part of this annual report.

Finally, we will summarize our efforts in 2018 regarding exploitation rates of BNT in Warm Springs Creek near the mouth of Burns Creek. This small spring-fed system is a popular fishery with good access for anglers. We wanted to learn more about exploitation levels of BNT in this fishery and whether BNT in Warm Springs Creek function as a connected component of the BNT population in the South Fork or an isolated metapopulation as we had heard from anglers concerned about potential overharvest of BNT. Thus, our goal was to quantify exploitation levels in this stream and evaluate connectivity with the South Fork.

METHODS

South Fork Population Monitoring

The methodology for annually monitoring fish abundances and trends in the South Fork, operating and evaluating the tributary weirs, assessing the effects of spring flows on YCT and RBT recruitment, and implementation and analysis of the AIP, may be found in detail in Schoby et al. (2013). Methods used in 2018 were identical to those outlined in the referenced report.

In addition to methods used during previous years, we compared length-weight relationships for each trout species caught at the Lorenzo and Conant monitoring reaches of the South Fork. During the electrofishing surveys, we weighed a subsample of each species at each of the electrofishing reaches. We then compared these observed weights with standard weights calculated for each species. We used the standard published by Kruse and Hubert (1997) for YCT, the standard published by Simpkins and Hubert (1996) for RBT, and the standard published by Milewski and Brown (1994) for BNT. We calculated relative weights (*Wr*) for each of the sampled trout that were weighed and compared these with relative weights from 2002, 2003, and 2012 through 2017 for trout at the Lorenzo Reach and with relative weights from 2002, and 2012 through 2017 for trout at the Conant Reach. We also compared relative weights for trout captured at the Lufkin monitoring reach from 2014 through 2016. Comparisons were made using 95% confidence intervals for 100 mm length-groups where non-overlapping intervals were considered statistically significant at the $\alpha = 0.05$ level. We also calculated relative weights for MWF using the standard equation published by Rogers et al. (1996). We calculated catch per unit effort (CPUE) for MWF during the recapture run. We calculated a confidence interval around the average CPUE by using each separate workup batch during the marking run as the sampling unit, which will allow for CPUE comparisons during future sampling events.

Creel

We conducted a creel survey on the South Fork from April 2017 through March 2018 to estimate annual rates of angling effort, catch, and harvest. Monthly estimates of catch, effort, and harvest were generated for the South Fork Snake River during this survey using an Access–Access Design with completed trip data and an Access–Roving Design with incomplete trip data (Pollock et al. 1994). We also estimated the number and average duration of fishing trips on the South Fork on a monthly basis for comparison to prior surveys. Estimates for total catch, effort, and harvest were the sum of the completed trip estimates and the incomplete trip estimates by month.

We divided the year into two-week intervals. From January through March, and November through December, creel clerks interviewed anglers at river access sites four times during each two week time interval; two weekdays and two weekend days or holidays. During the remainder of the year, when angler effort was higher, clerks conducted interviews six times per two week time interval (i.e., three weekdays and three weekend/holiday days). The days selected for creel interviews were selected randomly using a random number generator. We divided the river into three segments to allow creel clerks the ability to cover an entire segment during a creel work shift. These sections were the upper river from Palisades Dam downstream to the Conant boat access, the canyon section from Conant downstream to the Heise Bridge, and the lower river section from the Heise Bridge downstream to the confluence with the Henrys Fork Snake River. The river section selected for each creel day was determined by randomly assigning the first day in January for both the weekdays and weekend/holiday strata and systematically going through each river section for each strata for the remainder of the year (i.e., each section was equally weighted). Creel interviews were conducted during daylight hours, and days were divided into three periods, the AM period from sunrise to 1100 hours (morning), the noon period from 1100 hours to 1600 hours (afternoon), and the PM period from 1600 hours to sunset (evening). These three time periods were weighted with the following probabilities to proportionally allocate sampling relative to expected effort, utilizing the following ratios: 15% for the morning period, 40% for the afternoon period, and 45% for the evening period. Creel clerks were instructed to be at designated access points in the designated river section throughout the creel shift. There were four to five designated access sites where clerks conducted interviews. Creel clerks were given a schedule with a set amount of time to be spent at each site before moving to the next access point (Pollock et al. 1994). The time designated for each site was weighted by how much angler use occurred there, i.e. clerks worked at popular boat ramps longer than at roadside bank angler access sites. The primary goal was to collect completed trip data from anglers leaving the access sites, but clerks also collected incomplete trip data from anglers who were still fishing when the survey period ended. Creel clerks randomized which of the designated access sites to start at each day and which direction to move through the sites by rolling a numbered game die.

Effort was estimated using aerial counts by using a fixed-wing airplane and pilot to collect instantaneous counts of anglers for the entire river. Counts were conducted on one weekday and one weekend/holiday during each two-week interval. The days and flight start times were selected randomly using a random number generator. Total angling effort in angler hours on day *d* ($\hat{E}_d$) was estimated as:

$$\hat{E}_d = T_d \bar{I}_d, \qquad (1)$$

where T_d is the total number of hours in the fishing day and $\bar{I}_d$ is the mean of the angler counts conducted on day *d*. Effort for each two week interval was calculated using:

$$\hat{E}_k = N_k \frac{\sum_{d=1}^{n_k} \hat{E}_d}{n_k}, \quad (2)$$

where N_k is the number of days in the stratum and n_k is the number of days surveyed in the stratum. Effort for each two week interval during the survey was summed to calculate total fishing effort ($\hat{E}$). Estimates of effort among strata can be summed to estimate effort ($\hat{E}$) over the duration of the fishing season or time period of interest. We used an approximation of the within-stratum variance ($\hat{V}(\hat{E}_k)$) to ultimately obtain confidence intervals for the estimate of effort (Pollock et al. 1994; Scheaffer et al. 2006; Su and Clapp 2013) using:

$$\hat{V}(\hat{E}_k) = {N_k}^2 \left(\frac{s_{\hat{E}_k}^2}{n_k} \right), \quad (3)$$

where $s^2_{\hat{E}_k}$ is the sample variance which is calculated as:

$$s^2_{\hat{E}_k} = \frac{\sum_{d=1}^{n_k}(\hat{E}_d - \bar{E}_k)}{n_k - 1}, \quad (4)$$

where $\bar{E}_k$ is the average daily effort estimate over the stratum. Similar to the point estimate, the overall season variance ($\hat{V}(\hat{E})$) was calculated as the sum of the estimated strata variances. A CI for estimated angling effort over the sampling period ($CI_{\hat{E}}$) was estimated as:

$$CI_{\hat{E}} = \hat{E} \pm Z_{\alpha/2}\sqrt{\hat{V}(\hat{E})}, (5)$$

where $Z_{\alpha/2}$ is the desired critical value for the CI (e.g., 1.96 for a 95% CI).

We used a multi-day catch rate estimator for each stratum as:

$$\hat{R}_{2k} = \frac{\sum_{i=1}^{j_k} c_i}{\sum_{i=1}^{j_k} h_i}, (6)$$

where j_k is the total number of anglers interviewed in the stratum. Stratum variance of the multi-day catch rate ($\hat{V}(\hat{R}_{2k})$) is estimated as:

$$\hat{V}(\hat{R}_{2k}) = \frac{1}{(\bar{h}_k)^2 j_k} S^2_{\hat{R}_{2k}}, \quad (7)$$

Catch was estimated for each two week interval using the multi-day estimator with ($\hat{C}_{2k}$) estimated as the product of interval effort and catch rate:

$$\hat{C}_{k2} = \hat{E}_k \hat{R}_{2k}. \quad (8)$$

Variance of catch for the interval was estimated as the variance of a product (Goodman 1960):

$$\hat{V}(\hat{C}_{2k}) = \hat{E}_k{}^2 \hat{V}(\hat{R}_{2k}) + \hat{R}_{2k}{}^2 \hat{V}(\hat{E}_k) - \hat{V}(\hat{R}_{2k})\hat{V}(\hat{E}_k), \qquad (9)$$

Estimated catch and variance among intervals were then summed to estimate season catch ($\hat{C}_2$) and season variance ($\hat{V}(\hat{C}_2)$). A CI ($CI_{\hat{C}_{md}}$) was estimated as:

$$CI_{\hat{C}_2} = \hat{C}_2 \pm Z_{\alpha/2}\sqrt{\hat{V}(\hat{C}_2)}. \quad (10)$$

Palisades Creek

We used multiple-pass backpack electrofishing sampling depletion techniques to estimate abundance of salmonids in the Palisades Creek drainage in 2018. We sampled a total of 41 randomly selected 100-m sites. Of these, 14 sites were previously sampled (Meyer and Lamansky 2004) and provided data points on trend information. Additional sites were included to allow us to better estimate total YCT abundance in the Palisades Creek drainage. The additional sites were randomly selected from all of the potential 100-m reaches in the Palisades Creek drainage at the 1:24,000 scale. In an effort to minimize confidence bounds around the drainage-wide estimate, we limited the number of sites selected in first order streams known to be intermittent and proportionally increased the number in perennial first order, and third-order streams (Meyer et al. 2006). We calculated the percent of stream in first order intermittent streams, first-order, second-order, and third-order streams by dividing the length of the respective stream orders by the total length of Palisades Creek. These percentages were used to weight the stream orders according to the percentages they made up for the whole of Palisades Creek. We multiplied the percent of the drainage in these orders by the following weights: 0.1 for intermittent first order, 0.5 for perennial first order, 0.1 for second order, and 0.3 for third order. This provided the number of survey sites for each stream order given our goal of sampling 41 sites. We then used a random number generator to select which of the available 100-m reaches within each stream order to include. We used the IDFG standard stream survey methodology to sample the sites and estimated abundances of each species for fish ≥100 mm and <100 mm TL. When stream widths exceeded 3 m, two backpack electrofishing units were used. The drainage-wide estimate was made using the stratified-random-sampling formulas of Scheaffer et al. (1996) to calculate abundance totals and variance for each stream order and a total abundance and associated variance.

Rainey Creek Eyed-Eggs

We stocked eyed-eggs into the lower section of Rainey Creek. Adult, wild YCT brood fish were collected from the South Fork near the mouth of Rainey Creek and held in separate male/female cages placed in Rainey Creek near the electric weir. We spawned these brood fish on three separate dates, June 12, June 20, and June 27. Unripe fish were returned to holding cages after the first two spawning dates to wait for them to become ripe. Ripe fish were spawned by staff from IDFG's Grace and American Falls hatcheries. We sacrificed all brood fish and sampled them for pathogens and viruses while fertilized eggs were rearing at Henrys Lake Hatchery. Pairings were one:one female and male ratios. Eggs were grouped into two family groups per tray and reared at Henrys Lake Hatchery. Eggs for each group were kept in separate heath trays, which allowed us to cull diseased eggs, depending on test results from the IDFG Eagle Fish Health lab.

Developing eggs reached the eyed stage roughly 28 d after fertilization. We picked dead eggs prior to enumerating eyed-eggs on the date they were packed into Whitlock-Vibert boxes and stocked in Rainey Creek July 10, July 18, and July 25. We transported the eggs/boxes to Rainey Creek and installed them into the gravel of tail-outs from pools and run habitats in two different reaches. The upper one was near the US Forest Service boundary at the old weir site, and the section of Rainey Creek approximately 10.5 river km upstream from the mouth.

We captured YCT fry from Rainey Creek using backpack electrofishing. Backpack electrofishing (i.e., spot shocking) was conducted between the Rainey Creek weir and the US Forest Service boundary on September 11 and 12. Genetic samples from fry, as well as the adults used for brood, were analyzed at the Eagle Fish Genetics Lab using Parental Based Tagging (PBT) techniques to identify fry produced by the eyed-eggs stocking.

Rainbow Redd Electrofishing

We used boat-mounted electrofishing gear to remove RBT from a localized spawning redd near Indian Creek on the South Fork. The same redd was electrofished twice per week through the spawning season to determine if removing spawning RBT from a redd complex led to depletion or not in terms of reduced catch. Additionally, on two of these dates, we completed two successive passes to determine if catch rates remained similar with multiple removals conducted on the same day. Since we electrofished the same area each week through the spawning season, we simply used total daily catch to evaluate the effects of weekly electrofishing on removal rates from spawning beds. We identified sex based on morphology and expression of gametes, which enabled us to evaluate sex-based trends through the course of the spawning season.

Third Creek Habitat Restoration

We restored 0.8 km (0.5 miles) of Third Creek, a spring creek tributary of lower Rainey Creek. The section we performed this habitat restoration work on was private property, owned by two different landowners. Both landowners were important collaborators on this project, donating time, skills, equipment, and money to make the project possible. One landowner initiated a stream condition assessment through Wild Waters Restoration prior to IDFG becoming involved in the project. We continued to work with Wild Waters to finalize the assessment, project design, and oversight of implementation

The project was designed to reduce stream widths from an average of 7.3 m to 1.8 to 2.4 m. The undersized culvert was replaced with a 1.5-m diameter squashed pipe. Stream narrowing allowed for increased sinuosity to be incorporated in the design, so 53 meander bends were created and whole tree revetment was planned for 25% (13) of these bends to increase large woody debris with four trees used at each of these selected bends. Willows were planted in the riparian area, which included poles, whole clumps, and mattresses. Wetland sod was harvested in off-channel wetland areas nearby on both properties and planted on the restore banks after the channel was narrowed. Fine sediment was removed from the channel and clean gravel (obtained during excavation along the stream margins) was placed in the channel. A local contractor was hired to perform the work during base flow conditions in fall.

Warm Springs Creek Exploitation

We used the IDFG “Tag You’re It” program to evaluate exploitation of wild BNT in Warm Springs Creek located along the South Fork near the mouth of Burns Creek (Figure 1). On June 6, we used rafts outfitted with electrofishing equipment to capture BNT. We electrofished at night due to the clear, deep water associated with this ponded section of Warm Springs Creek. We marked all BNT with T-bar anchor tags that had reporting information and tag ID numbers printed on each tag. Anchor tags were printed with a unique identification number, phone number, and website address where anglers could report the tag using the “Tag You’re It” statewide tag reporting system (Meyer and Schill 2014). On June 7, we floated the rafts down the South Fork to the nearest boat ramp (Fullmer) which is 1.8-km downstream. We electrofished this section of the river as well, and marked additional BNT with anchor tags in this short section of river. We used tag return information from the “Tag You’re It” program to evaluate exploitation of BNT in Warm Springs Creek and to determine if BNT were migrating into or out of Warm Springs Creek from or to the South Fork.

We used data obtained from reported tags to estimate exploitation, caught and released fish, and total angler use. We estimated the angler reporting rate (λ) using the average reporting rate of non-reward tags in the current study relative to the high-reward tags of hatchery Rainbow Trout as estimated by Meyer et al. (2012):

$$\lambda = \frac{\mathrm{R}r \ \div \ \mathrm{R}t}{\mathrm{N}r \ \div \ \mathrm{N}t}, \quad (11)$$

where R*r* and R*t* are the numbers of non-reward tags released and reported, respectively; and N*r* and N*t* are the numbers of high-reward tags released and reported (Pollock et al. 2001). We assumed a $200 reward tag reporting rate of 100% (Meyer et al. 2012). In the current study, we used statewide averages to estimate tag loss and tagging mortality of Brown Trout (Meyer and Schill 2014). We estimated angler exploitation (u') using the equation:

$$u' = \frac{u}{\lambda\,(1 - Tag_l)(1 - \ Tag_m)}, \quad (12)$$

where u is the number of non-reward tagged fish that were reported as harvested divided by the total number of non-reward tagged fish, Tag_l is the first year tag loss rate (i.e., 0.088), and Tag_m is the tagging mortality rate (i.e., 0.01). We used the tag loss and tagging mortality as reported by Meyer and Schill (2014). We also estimated angler use by modifying u to include fish reported as caught and released.

RESULTS

South Fork Population Monitoring

We captured 1,104 trout at the Lorenzo monitoring reach, including 290 YCT, 40 RBT, and 713 BNT. Our abundance estimates include age-1 and older YCT (≥ 102) and BNT (≥ 178). We estimated YCT densities at 286 fish/km (± 76, Figure 2). The total trout estimate at Lorenzo for age 1 and older YCT, RBT, and BNT combined was 1,971 trout/km (± 559). The trend for YCT density estimates at Lorenzo from 1987 through 2003 was stable as indicated by an intrinsic rate of change (r) of -0.01 which was not significantly different than zero at the $\alpha = 0.10$ level (F = 0.153, df = 9, P = 0.71). Since 2005, YCT abundance has statistically increased (at the $\alpha = 0.10$ level) with an intrinsic rate of growth of 0.06 (F = 4.372, df = 11, P = 0.06). Relative weights for YCT at Lorenzo were similar to recent years with an average of 94 (Figure 3). We estimated BNT densities to be 653 BNT/km (± 124) at Lorenzo (Table 1; Figure 2). The BNT population at Lorenzo had a significantly increasing trend over the 1987 through 2003 time period with r = 0.09 (F = 17.488, df = 9, P = 0.003). Since the start of the three-pronged management approach on the South Fork, BNT abundance at Lorenzo has had a stable trend with r = -0.02, which was not significantly different than zero (F = 0.684, df = 13, P = 0.42). Brown Trout relative weights in 2018 averaged 92 and were similar to previous years (Figure 4). We did not sample enough recaptures to estimate abundance of RBT. However, RBT represented 3.8% of the total catch for all species combined. Extrapolating this percent on the total trout estimate would indicate we have roughly 75 RBT/km. Relative weights for RBT at Lorenzo averaged 100, and were similar to previous years (Figure 5).

We captured a total of 3,293 trout at the Conant monitoring reach. This included 1,136 YCT, 1,395 RBT, 760 BNT, and two Lake Trout *Salvelinus namaycush*. We estimated the total trout density at 3,915 trout/km (± 263) at Conant. We estimated there were 1,137 age-1 and older YCT/km (± 70, Table 2; Figure 6). Prior to the three-pronged management approach on the South Fork (1982–2003), YCT at the Conant monitoring reach experienced a statistically significant decrease in abundance, with an intrinsic rate of growth of -0.04 (F = 11.697, df = 13, P = 0.005). Since management changed to the three-pronged management approach in 2004, YCT at Conant have experienced an increasing trend in abundance with $r = 0.03$ ($F = 3.362$, $df = 14$, $P = 0.09$). Relative weights for YCT at Conant were similar among years (Figure 7). In 2018, the average relative weight was 95. We estimated there to be 836 age-1 and older BNT/km (± 129) at Conant. Brown Trout abundance prior to the three-pronged management approach (1982–2003) was stable ($r = 0.01$, $F = 0.542$, $df = 13$, $P = 0.48$). Since 2004, BNT abundance has increased at Conant with an intrinsic rate of population growth rate of 0.07 ($F = 14.179$, $df = 14$, $P < 0.01$). Brown Trout relative weights were stable among years and averaged 92 in 2018 (Figure 8). We estimated there to be 1,907 age-1 and older RBT/km (± 249) in the Conant monitoring reach in 2018. Between 1982 and 2003, RBT abundance has increased ($r = 0.18$, $F = 85.489$, $df = 11$, $P \leq 0.001$). From 2004 through 2018, RBT abundance has increased ($r = 0.06$, $F = 7.794$, $df = 14$, $P = 0.02$). Relative weights for RBT at Conant were similar for all size groups among recent years and averaged 97 in 2018 (Figure 9).

We captured 1,584 trout at the Lufkin monitoring reach. This included 610 YCT, 429 RBT, and 545 BNT. We estimated the total trout density at 4,340 trout/km (± 437) at Lufkin. We estimated there were 1,064 age-1 and older YCT/km (± 269, Table 3; Figure 10). Relative weights for YCT at Lufkin were similar to previous years and averaged 90 (Figure 11). We estimated there to be 814 age-1 and older BNT/km (± 154) at Lufkin. Brown Trout relative weights were similar to previous years and averaged 91 in 2018 (Figure 12). We estimated there to be 1,386 age-1 and older RBT/km (± 348) in the Lufkin monitoring reach in 2018. Relative weights for RBT were similar to previous values at Lufkin and averaged 94 in 2018 (Figure 13).

Creel

Anglers fished an estimated 421,310 h on the South Fork during a consecutive 12-month period from April 2017 through March 2018. The lower and upper confidence bounds for this annual effort estimate ranged from 401,451 to 441,871 h. Annual fishing effort estimates and confidence limits for the Upper, Canyon, and Lower South Fork sections were 165,553 (155,334-176,012) h, 162,650 (146,235-179,442) h, and 93,107 (86,364-99,918) h, respectively. Angler effort in the Upper and Canyon sections peaked in late August with 41,788 and 55,148 h, respectively for a two-week time interval while angler effort in the Lower section peaked in mid-September at 22,471 h (Figure 14). The majority of the angling effort was by boat anglers who fished an estimated 324,087 h while bank anglers fished an estimated 97,371 h (Table 4). Boat anglers spent an estimated 125,880, 142,862, and 55,344 h fishing in the Upper, Canyon, and Lower sections, respectively. During the survey period, bank anglers spent 39,663 h fishing in the Upper section, 19,893 in the Canyon, and 37,814 h in the Lower section.

Anglers caught an estimated 336,412 fish during the yearlong survey with a 95% confidence interval ranging from 280,926-388,604 fish. Most of the fish (91%) were caught by boat anglers (Table 5). With regard to location, anglers caught most fish in the Canyon section, followed by the Upper and Lower sections of the South Fork during the survey (Table 6). Yellowstone Cutthroat Trout were the most commonly caught fish species, followed by MWF, RBT, and BNT (Table 6). Anglers caught nearly equal numbers of RBT in the Upper and Canyon sections. Yellowstone Cutthroat Trout comprised roughly 40% of the catch in each of the river sections (Table 6). Fly anglers caught most of the fish, followed by lure, and bait anglers (Table 7). The overall catch rate for the South Fork during the creel survey was 0.8 fish per hour.

The total annual estimate of harvested fish in the South Fork during the survey was 9,437 fish with a lower and upper 95% confidence bounds ranging from 4,692-15,906 fish. The harvest component of the fishery was dominated by RBT (8,667 fish), with BNT also contributing (697 fish), and token amounts of MWF (21 fish) and illegally-harvested YCT (52 fish; Table 8). The majority of the RBT harvest occurred in the Upper Section. Thus, most of the harvest occurred in the Upper Section, followed by the Canyon and Lower sections (Table 6). River-wide, boat anglers harvested 31% of the fish while bank anglers harvested 69% of the total harvest (Table 5).

Weirs

From April 3 through July 6, we captured 1,312 migrating trout at the Burns Creek weir, including three male and six female RBT, and 1,303 YCT (660 males and 643 females). We measured fallback rates as the number of male and female YCT to move downstream of the weir after being handled at the trap which were recaptured again at the trap at a later date. This allowed us to get accurate escapement estimates. We observed 26% of the male YCT and 13% of the female YCT captured at the Burns Creek trap fell back over the weir. We captured 50 fluvial-sized YCT upstream of the Burns Creek weir using backpack electrofishing gear, and found all 50 were marked. Thus, the 2018 trapping efficiency estimate for the Burns Creek weir was 100% (Table 9).

We operated the Pine Creek weir from April 2 through June 26, capturing a total of 2,081 fish, of which six were RBT (three males and three females). The 2,075 YCT included 993 males and 1,082 females. The fallback rates were 8% for male YCT and 6% for female Cutthroat Trout. Upstream of the weir, we again used backpack electrofishing units to collect a sample of fluvial-sized fish and caught a total of 31 YCT, of which 29 had marks, resulting in a 94% efficiency estimate for the Pine Creek weir.

We operated the Rainey Creek weir from April 2 through June 26, capturing a total of 37 trout, all of which were YCT. The 37 fish included 12 male and 25 female YCT. None of these YCT fell back through the Rainey Cr weir and were later re-trapped, resulting in a 0% fall back rates for YCT.

At the Palisades Creek weir, we caught a total of 818 trout between April 2 and July 10. We caught 18 RBT including eight males and ten females. The remaining 478 fish were YCT and included 175 male YCT and 303 female YCT. Fallback rates for male YCT were 10% and 3% for female YCT. We captured 49 YCT migrating downstream through the Palisades Canal bypass channel. Of these, four were unmarked, yielding a Palisades Creek Weir trap efficiency estimate of 92%.

Spring Flows

Higher spring flows in the South Fork were significantly correlated with increased abundance of age-1 YCT the following year (Figure 15). Maximum spring flows released from Palisades Dam were positively related with increased age-1 YCT abundance (F = 5.795, df = 12, P = 0.03). Analysis of residuals indicated data were normally distributed.

The abundance of age-1 RBT was not correlated with spring flows the previous year. Analysis of residuals indicated age-1 RBT data were not normally distributed, so we log-transformed age-1 RBT abundance and regressed these with log-transformed maximum spring flow values for the prior year (Figure 16). Log transformations normalized the data. However, age-1 RBT abundances were not significantly correlated with maximum spring flows (F = 4.544, df = 13, P = 0.05).

South Fork Angler Incentive Program

In 2018, we continued the AIP. We marked a total of 2,068 RBT with coded wire tags (CWT), including 1,793 RBT with $50 tags, 200 with $100 tags, 50 with $200 tags, 20 with $500 tags, and 5 fish with $1,000 tags. We marked RBT during two seasons in 2018 with 777 RBT marked between Palisades Dam and Heise during February, and several fish during fall population surveys, including; 36 RBT marked at the Lorenzo site, 449 at the Lufkin monitoring site, and 806 RBT marked at the Conant monitoring site. A total of 104 anglers turned in 3,205 RBT in 2018 (Figure 17). Overall, anglers turned in an average of 31 RBT. Of the 3,205 RBT checked by IDFG, there were 102 tagged fish. The tag values and number that were turned in were $50 (75), $100 (18), $200 (8), $500 (20), and one $1,000 for a total of $9,150.

Palisades Creek

We sampled 41 sites in the Palisades Creek drainage in 2018 between July 24 and August 21. These included 24 first order sites, six second order sites, and 11 third order sites (Figure 18). Of these sites, 14 were sites that had been included in previous surveys. Six of the sites were dry when visited during summer base flows, all of which were first order stream sites. Another site (site 25) was removed from the survey for safety concerns because of high, fast, and dangerous water. We captured YCT and RBT during the survey. We captured RBT at five sites (sites 20 through 24) which were located downstream of Lower Palisades Lake. We captured YCT at 13 of the 24 first order sites, all six of the second order sites, and all ten of the third order sites sampled. Rainbow Trout were only captured in third order sites. The average density of YCT/100 m^2 was 0.20, 0.27, and 0.36/100 m^2 for stream orders one through three, respectively. The drainage-wide estimate and 95% confidence interval for YCT ≥100 mm in the Palisades Creek drainage was 6,582 (±3,293).

Rainey Creek Eyed-Eggs

We spawned 44 female YCT with 44 male YCT collected from the South Fork June 5 and June 12 using boat electrofishing to capture adult fish. We spawned twelve females on June 12, six females on June 20, and 27 female YCT on June 27. Fertilized eggs were eyed-up at Henrys Lake Hatchery. Disease testing did not indicate eggs needed to be culled prior to stocking. Once the developing eggs reached the eyed stage, we estimated there to be 42,900 eggs. We picked dead eggs prior to stocking (averaging 25 eggs/female or 50 eggs per tray) and stocked eyed-eggs in Rainey Creek on July 10, July 18, and July 25. We stocked roughly 20,000 eggs in each of two different locations of Rainey Creek, one near the Forest Boundary and another between the Forest Boundary and the weir.

We used backpack electrofishing during the fall to capture fry in Rainey Creek to evaluate the impact of eyed-egg stocking. We collected 100 fry for the genetic sample, and 99 of these were successfully genotyped by the IDFG Eagle genetics lab. Nine of these fry (9%) were from eyed-egg sources. These fry came from six different females spawned. One of the 99 fry was the progeny of wild, fluvial parents passed at the Rainey Creek weir.

Rainbow Redd Electrofishing

We electrofished a known RBT redd complex near Indian Creek nine times between April 13 and May 16. All RBT captured were removed from the redd complex during each event. Catch rates ranged from 8 to 33 RBT with an average of 19 fish when removals had a two day or longer sampling frequency interval. Despite repeated removals, catch rates did not significantly decline through the spawning season (regression slope = -0.37 which was not significantly different than 0, F = 4.287, df = 8, P = 0.07). Two consecutive electrofishing passes were conducted on two dates. On May 9, we captured 9 fish on the first pass and 5 RBT on the second pass. On May 14, we caught 6 RBT on the first pass, and 2 RBT on the second.

Third Creek Habitat Restoration

We restored 0.8 km (0.5 mile) of Third Creek, a spring fed tributary of Rainey Creek downstream of the weir. This section of Third Creek runs through two different private properties, and the landowners of each piece were partners on the project. A pond and an over-widened channel were contributing to this section reaching temperatures of up to 23 ºC during July of 2017, despite spring sources provide inputs at 5 ºC. The pond was created by a road crossing where water was backed up behind an undersized culvert (0.3 m diameter or 12 inches). We replaced the undersized pipe with a 1.5-m diameter culvert, which was sized to provide ample passage of flow and terrestrial animals. The project was initiated on September 15, 2018 and completed roughly one month later. We narrowed the stream channel from an average width of 7.3 m to 1.8 - 2.4 m. We planted approximately 6,000 willow staves in the riparian area and placed wetland sod over the restored stream banks. The willow staves were collected from nearby USFS property and IDFG property by IDFG staff, volunteers, and South Fork Initiative staff. The same people also placed the willow staves with help from the landowners. The plantings occurred during construction. The banks were built up using silt and fines from the disturbed channel, and gravels were placed in the stream bed to the designed grade. Finally, a series of pools, runs, and glides were built into the restored channel with large woody debris anchoring the pools and providing fish cover. For more information on this restoration, please view our summary video at https://www.youtube.com/watch?v=nHN0FiRSzbw.

Warm Spring Creek Exploitation

We marked 210 BNT in Warm Springs Creek near the mouth of Burns Creek with T-bar anchor tags in order to assess exploitation. The total lengths of BNT ranged from 159 to 605 mm and averaged 405 mm. We also marked 10 BNT in the South Fork between Burns Creek and the Fullmer boat ramp 1.8 km downstream. These fish had total lengths ranging between 310 and 471 mm and averaged 402 mm. Over a 13-month time period post release, four marked BNT were reported by anglers. All fish were marked in Warm Springs Creek. Three were caught and released in Warm Springs Creek and one was caught and harvested in the South Fork slightly upstream of the Byington Boat Ramp, which is located 20 river km downstream from the confluence of Warm Spring Ck. The angler use rate was 25%, after adjusted for reporting bias, tagging mortality, and tag retention was 25%. The adjusted harvest rate was 6%, meaning 6% of the Brown Trout tagged in Warm Springs Creek were harvested by anglers during the 13 months after tagging.

DISCUSSION

South Fork Population Monitoring

Trends of YCT abundance within the Lorenzo monitoring reach in the lower South Fork indicate numbers have increased since the initiation of the three-pronged management approach of managing spring flows, protecting important spawning tributaries from RBT invasion, and encouraging harvest of RBT. Abundance of Brown Trout in the lower South Fork has also remained high and stable after the three-pronged management approach was implemented by IDFG. While increasing YCT population trends suggests the three-pronged approach is working overall, the level of impact in the lower river is not as pronounced as what was observed in the upper river. It is possible that other factors besides spring flows, tributary spawning refugia, and harvest of RBT influence population parameters for trout species residing in the lower South Fork. Beyond improved trends for trout abundance, trout body conditions (i.e., relative weights) appear to be stable as well.

Rainbow Trout have experienced increasing or stable trends in the upper South Fork since the initiation of the three-pronged management approach in 2004. The RBT population has exhibited an increasing intrinsic rate of population growth in all years with the exception of 2016 to 2017. With the addition of 2018 data, the RBT trend changed from a stable to a statistically increasing population, yet again. This is a result of recruitment of a large year class of age-1 RBT. We have observed recruitment of strong year-classes for RBT in the recent past. The most recent one was the 2008 recruitment year (High et al. 2011). This strong recruitment year nearly doubled the RBT population, and led to the initiation of the South Fork AIP. The effects of this current RBT population change needs to be closely monitored to determine if additional management actions to reduce RBT abundance are warranted.

Within the middle section of the South Fork, the trout community composition shifts from nearly equal proportions of YCT, BNT, and RBT (as seen in the upper river), to a BNT-dominated, YCT- present composition (as seen in the lower river). In 2014, we started sampling the Lufkin reach, to periodically assess fish abundances and species composition within the middle section of the South Fork. If changes in species composition start to occur in the South Fork, we would anticipate observing these changes at the Lufkin monitoring reach. No significant change in YCT or BNT abundance was observed in the Lufkin and Conant reaches, but RBT abundance increased significantly in both sections. We should continue to closely monitor RBT abundance and trends, to allow for timely management actions, if warranted. Increased exploitation and suppression of RBT may be necessary to further YCT conservation efforts.

Creel

The creel survey indicated angling effort has continued to increase on the South Fork and 2018 is the highest we have estimated. Most of the angling effort is occurring during mid-summer months in the Upper and Canyon sections, which coincides with the majority of aquatic and terrestrial bug hatches and nice weather. Interestingly, fishing effort from boat anglers did not increase from the previous survey conducted in 2012. While boat anglers represented the majority of angling effort in the current survey, the annual effort by boat anglers was similar to 2012. The increase in total effort between surveys resulted from the near doubling of effort by bank anglers. Bank angling effort estimates were similar for the Upper and Lower sections, but were much lower in the Canyon section, which is more difficult to access and contains a roadless section. Although boat anglers spent more time in the Upper section than the Lower section, bank angling effort estimates were similar for each section. This indicates bank anglers were just as likely to fish in the Lower section as in the Upper section, despite the fact that the Lower section supports lower trout densities and a less diverse fish assemblage. Access likely plays a role in this, but proximity to the more populated cities in the area may also be contributing to how frequently anglers fish the lower South Fork.

Yellowstone Cutthroat Trout continue to be a large part of the South Fork fishery based on catch estimates. Anglers caught nearly 335,000 YCT during the survey, and were surprisingly consistent in the proportion of catch throughout the river. Yellowstone Cutthroat Trout comprised roughly 40% of the catch in each of the three river segments, despite comprising less than that relative to species composition within those sections. Yellowstone Cutthroat Trout are known to be more vulnerable to anglers relative to Rainbow and Brown trout (Griffith 1993). Because of their catchability, especially via fly anglers who made up the majority of the anglers on the South Fork, Yellowstone Cutthroat Trout are an integral and important part of this popular fishery.

Although fly anglers made up the majority of the anglers on the South Fork, they were not proportionally represented in the harvest. Bait anglers caught 7% of the total catch while fly anglers caught 84%, however, relative to harvest, bait anglers accounted for 40% of the harvested fish. Part of this discrepancy may be due to residency, with bait anglers typically from local areas and thus more opportunity to become familiar with management efforts on the South Fork, where IDFG has been encouraging the harvest of RBT since 2004. Boat anglers, however, include non-resident and guided anglers, who may not be as familiar with YCT conservation efforts.

Most of the fish harvested from the South Fork during the survey were RBT and more RBT were harvested than were turned into the AIP. During the same time period as the creel survey (April 2017 through March 2018) anglers submitted 2,592 RBT as part of the AIP (IDFG unpublished data). With an estimated 8,667 RBT harvested during the same period, anglers turned in approximately 30% of the fish harvested to the AIP. During the last creel survey, we estimated that 6% of the harvested fish were turned in as part of the AIP (Schoby et al. 2014). This suggests that IDFG is having success improving and encouraging participation in the AIP, but also highlights room for improvement. We hope to continue to improve angler participation in the program and increase harvest of RBT by continuing to use social media and presentation opportunities to local angler groups to help inform anglers of the program. We also will reach out to local outfitters and guides and look for ways to help make participation by guides and guided clients easier. For example, having a dedicated collection freezer at the outfitter shop may increase participation by reducing time at boat ramp collection freezers.

Weirs

This was the fifth consecutive year since 2010 that we were able to operate weirs and traps effectively on all four major spawning tributaries of the South Fork. We observed relatively strong spawning runs of YCT in all tributaries, except Rainey Creek, and the total number of YCT captured at all of the weirs in 2018 (3,893 YCT) was the fifth highest during the last decade. This is likely the result of spawning adult numbers and high trapping efficiencies.

Rainey Creek continues to support relatively low numbers of spawning YCT, in comparison to the other tributaries. Only 37 YCT were caught at Rainey Creek for the second year in a row. IDFG has been trapping at Rainey Creek since 2001, with mixed success. From 2001 through 2010, the weir was located near the USFS boundary approximately 14 km upstream from the mouth of Rainey Creek. During this time period, a mix of floating panel and fixed picket weirs were employed. The median catch for this time period was 19 YCT with a range of 0 to 145 fish. We have not been able to estimate trapping efficiencies primarily due to small run sizes. However, we believe we were more efficient in 2010 when 145 YCT were captured because we were able to maintain the picket weir throughout the spawning run. In most years, pickets needed to be pulled for varying amounts of time during the early to middle portion of the runs because of high flows. In 2011, a new weir was constructed downstream, 5.1-km upstream of the confluence with South Fork, with the hope that we could protect more of the system from invading RBT. We anticipated higher catches with a trap located only 5.1 stream km upstream versus 14 stream km. The higher catches have yet to materialize. While adult YCT abundance has increased in the South Fork and adjacent spawning tributaries over the same period, spawning runs at Rainey Creek continue to be stagnant. It is possible that fluvial YCT in Rainey Creek have gone through a bottleneck, which is defined as a severe reduction in the demographic size of a population (Campbell 1990). If bottlenecks are severe enough, in-breeding depression can occur, which limits the ability of the population to recover because of reduced levels of reproductive fitness (Frankham 1995). Adverse genetic effects of bottlenecks in Rainey Creek are likely mitigated by the abundant resident YCT population in the upper portions of the system. However, the fluvial component of the Rainey Creek sub-population has not recovered, and does not show evidence for a trend towards recovery. Thus, an evaluation is warranted to assess limiting factors such as juvenile rearing and overwinter habitat or water temperatures and prioritize habitat restoration efforts within Rainey Creek. A better understanding of what is currently limiting YCT in Rainey Creek is currently unknown and could be a combination of bottlenecks and other variables.

During recent years, trap efficiencies at the electric Pine Creek weir have been lower than expected. These efficiencies, all less than 90%, were observed despite operating the electric weir at the highest settings (see Larson et al. 2014). One commonality of years with low efficiencies, was the absence of stop logs until later in the run. Stop logs are used to back up water levels on the upstream edge of the weir which results in more water flow through the fish trap area creating attractive flows for migrating trout at the trap entrance. Stop logs cannot be left in place throughout the run because they catch debris, cause damage to the structure, and kill migrating YCT by entangling them in debris and holding the fish within the electric field. These issues subside once peak flows start to subside. With the stop logs in place, a slight physical obstacle is introduced in the electric field of the barrier. We hypothesized that adding an obstacle like this may increase efficiencies because it limits the passage of fish with high swimming velocities and momentum moving through the electric barrier even when electricity impairs their control of direction or speed. In 2018, we were able to test this hypothesis by placing the stop logs prior to the peak of the spawning run when stream flows were low. This resulted in the highest trap efficiency recorded at Pine Creek since weir construction (Table 9). In order to maximize trapping efficiency at Pine Creek, the stop logs should be installed in the weir as soon as possible to provide a slight physical obstacle to maximize trap efficiency.

Spring Flows

Increases in spring flows benefit YCT recruitment, but are not necessarily correlated with reduced RBT recruitment. Since 2004, increases in maximum spring flows are correlated with increasing abundance of age-1 YCT the following year. The relationship between higher maximum spring flows and higher age-1 YCT recruitment are likely related to the fact that dynamic spring flows act as a spawning cue as flows decrease (Thurow and King 1994; Henderson et al. 2000). Tributary flows are positively related to higher snowpack, which benefit YCT recruitment (Varley and Gresswell 1988). The abundance of age-1 RBT was not significantly correlated with flows, suggesting maximum flows did not reach levels sufficient to disturb developing embryos or

displace newly emerging fry. This finding corroborates previous studies on the South Fork that indicated spring flows peaking at 422 m^3/s were not sufficient to move small radio transmitters placed in RBT redds (Schrader and Fredericks 2006a) nor mobilize substrate until flow reaches 736 m^3/s (Hauer et al. 2004). Previous studies performed on the South Fork indicate flows in excess of 708 m^3/s are required for geomorphic processes to start altering stream channels (Hauer et al. 2004), which provide the most benefit to YCT (Moller and Van Kirk 2003). While we could not detect a statistically significant correlation between maximum spring river flows and age-1 RBT abundance the following year, our dataset does not include maximum flows within the range suggested by Hauer et al. (2004).
South Fork Angler Incentive Study.

The South Fork AIP plays an important role in IDFG's management of YCT in the South Fork. This program provides a tool for outreach and education about the importance of Yellowstone Cutthroat Trout conservation in the South Fork. This, of itself, may be enough justification for how much benefit is derived given the program's low operational costs. However, recent population modeling efforts for how YCT populations respond to different levels of harvest and different scenarios of spring flows, indicate the Angler Incentive Program as part of the three-pronged management efforts on the South Fork is one of the key factors that is limiting the rate of RBT population growth, and has the potential to cause a population decline, particularly if harvest levels are increased (DeVita 2014). Creel data from the reporting period also indicate efforts to promote the AIP have been successful between 2012 and 2018 by an increase in the number of RBT harvested and reported to the program (see Creel).

Palisades Creek

The Palisades Creek drainage is the closest tributary drainage to Palisades Dam of the four main South Fork spawning tributaries, and was the first location in the South Fork where a wild-reproducing population of RBT was documented (Moore and Schill 1984). During this drainage-wide assessment, we did not find an expansion in the distribution of RBT. We observed RBT in the larger stream segments downstream of Lower Palisades Lake, while we observed YCT throughout the drainage at all the sites that supported fish. This drainage-wide survey and population estimate will be a valuable benchmark to which future fish abundance estimates and species distributions/compositions can be compared.

Rainey Creek Eyed-Eggs

This was our second year attempting to augment fluvial YCT runs in Rainey Creek by bolstering fry densities via stocking eyed-eggs. The true measure of success will be an increase in adult returns. Thus, evaluating the merits of this project using two years of results may not be informative. However, we did continue to learn during this second year of implementing this project. During the first year of implementation, we were successful at capturing ripe wild females from the South Fork as well as males, but the number of ripe female YCT we captured was the limiting factor, ultimately determining how many eyed-eggs we were able to stock in Rainey Creek. This year, we temporally spread out our collections from a single day to two different dates and held fish that we thought were close. In order to minimize time commitments from hatchery staff who assisted with the spawning, we held YCT we deemed close to being ripe in cages at the Rainey Creek weir separated with males in one cage and females in a second. Our hope was that by holding these fish that were close for a few days, we could have more ripe females to spawn on the days selected for spawning. However, this did end up being the case as the fish we held in the cages did not ripen. We're not sure why this occurred, but there were a few individuals that we held for three weeks over the peak of the spawning season, and they did not become ripe. It is possible that the difference in water temperatures between the main stem South Fork where the fish were captured and Rainey Creek, where they were held, inhibited the ripening process. At any rate, we were not able to increase the number of females that we spawned in 2018 over 2017, despite increasing sampling effort and holding fish. In future efforts, it may be worthwhile to utilize an approved fish hormone to induce ripeness in fish in addition to these efforts.

Rainbow Trout Redd Electrofishing

One of the objectives for the South Fork listed in the State Fisheries Management Plan is to reduce RBT abundance to less than 10% of the species composition at the Conant monitoring site (IDFG 2013). Much of the regional management efforts on the South Fork have worked to this end, including: 1. Reducing RBT recruitment by using tributary weirs to cull RBT during spawning runs (Schrader and Fredericks 2006a), 2. Increasing harvest by lengthening the fishing season and by eliminating daily bag limits (Schrader and Fredericks 2006b), 3. Working to procure high spring flows mimicking spring runoff to reduce RBT recruitment (Moller and Van Kirk 2003), and 4. Incentivizing harvest through the AIP (Schoby et al. 2014). While population models indicate these efforts have had an impact (DeVita 2014), we have not achieved the objective of reducing RBT to 10% or less of the species composition at Conant. One tool, which has not been used, is the manual removal of RBT from the South Fork via electrofishing. The main question concerning the implementation of this tool is whether or not it be effective at the population level. During previous research, boat-mounted electrofishing equipment proved a successful method for capturing large number of RBT from red complexes. During the spawning season, RBT are congregated on shallow spawning beds, and are more vulnerable to electrofishing gear. However, the number of redd complexes where large enough numbers of RBT can be removed during a single pass to have population-level impacts is limited (DeVita 2014). However, if RBT numbers on redd complexes are maintained through new fish immigrating into the area throughout the spawning season, then perhaps multiple removals could produce meaningful results. Our experiment this year documented RBT numbers were depleted with multiple passes in a single day but not if removals were spaced a few days apart. This suggests manual removal of RBT during spawning season may be an effective management tool to reduce the RBT population in the South Fork.

Third Creek Habitat Restoration

The restoration project on Third Creek, tributary of Rainey Creek was a successful endeavor from multiple viewpoints. This project was a collaborative effort with local landowners, IDFG, Bonneville Power Administration, the South Fork Initiative, and volunteers. The project demonstrated that there is a great deal of enthusiasm and interest in habitat restoration projects and conservation efforts in the South Fork, in general. IDFG received numerous inquiries from citizens, including two school groups, in how they could volunteer and participate in the project. Additionally, this restoration project provided an opportunity for the newly formed South Fork Initiative to become involved with restoration activities, and this organization may be able to leverage additional funds to make restoration projects easier to implement in future years. Finally, some preliminary evidence suggests the Third Creek restoration project was a success for Yellowstone Cutthroat Trout. Prior to construction, no trout were observed in this tributary. During construction, we observed Yellowstone Cutthroat Trout in the newly renovated pools hiding under large woody debris cover. Future monitoring efforts should be directed to document and quantify use of Third Creek habitat by YCT in coming years so future restoration efforts can benefit from lessons learned on Third Creek. While we view this project as a success, it was a relatively small project in terms of restoring YCT in Rainey Creek, where there is much left to be done. However, we hope results of these efforts on Third Creek will provide additional spawning and rearing habitat for YCT that was not previously available in the lower sections of Rainey Creek.

Warm Springs Creek Exploitation

Angler use of wild BNT in Warm Springs Creek was fairly high, but sustainable, as harvest levels were very low. Anglers caught a quarter of the BNT in Warm Springs Creek during this evaluation. Most of these fish were recaptured in Warm Springs Creek, but some were captured in the main stem of the South Fork Snake River. We documented that BNT from Warm Springs Creek move into the main river and contribute to the South Fork fishery. We also hoped to determine if BNT from mainstem South Fork move into Warm Springs Creek, which is possible since there are no fish barriers between the two. However, we did not document this upstream movement in this study, likely because of a small sample size with only ten BNT tagged in the main river near Warm Springs. Thus, we were unable to determine if BNT in Warm Springs represent a sub-population of BNT in the South Fork. Regardless, even if BNT from the main river do not migrate into Warm Springs, angler harvest levels within Warm Springs Creek (6%) are low enough that harvest likely plays a minor role in dictating trends of BNT. Brown Trout often have high annual mortality rates. In six different BNT populations in Pennsylvania, annual mortality rates varied from 45% to 81% (McFadden and Copper 1962). With only 6% exploitation of BNT in Warm Springs Creek, compensatory effects with natural mortality likely ameliorate any negative effects from angler harvest.

RECOMMENDATIONS

1. Continue to utilize weirs and traps on the four major spawning tributaries to provide spawning refugia for YCT and reduce range expansion and recruitment of RBT.

2. Expand RBT manual removal efforts by determining how much effort is required to remove several thousand RBT via electrofishing redds, and determining the logistical constraints associated with this effort.

3. Continue to use YCT eyed-egg stocking from wild brood stock to bolster YCT numbers in Rainey Creek.

4. Repeat the creel survey in 2021.

5. Continue to work with collaborators to implement stream restoration projects along Rainey Creek.

Table 1. Summary statistics from the Lorenzo monitoring site between 1987 and 2018 on the South Fork Snake River, including number of fish marked (M), number of fish captured C, number of fish recaptured R, capture efficiency (R/C), linear estimates for Yellowstone Cutthroat Trout (YCT), Rainbow Trout (RBT), Brown Trout (BNT), and all trout species combined. Standard deviations (SD) and coefficients of variation (CV) are also included for each estimate, and the average river flows (mean Q) during the sampling period are reported.

	Yellowstone Cutthroat Trout							Rainbow Trout							
Year	M	C	R	R/C	YCT/km	SD	CV	M	C	R	R/C	RBT/km	SD	CV	Mean Q (cms)
1987	146	63	6	9.5	422	207	0.25	2	0	0					65
1988	133	88	13	14.8	187	47	0.13	3	2	0					33
1989	119	74	13	17.6	248	98	0.20	1	2	0					25
1990	208	91	12	13.2	308	145	0.24	2	0	0					68
1991	199	175	17	9.7	445	146	0.17	0	6	0					72
1992															
1993	144	201	18	9.0	487	155	0.16	6	8	0					57
1994															
1995	264	196	22	11.2	568	116	0.10	4	5	0					36
1996															
1997															
1998															
1999	194	163	26	16.0	335	81	0.12	3	4	0					67

	Brown Trout							Total trout							
Year	M	C	R	R/C	BNT/km	SD	CV	M	C	R	R/C	trout/km	SD	CV	Mean Q (cms)
1987	225	102	12	11.8	531	160	0.15	380	168	18	0.1	970	97	0.10	65
1988	241	130	23	17.7	300	88	0.15	386	225	36	0.2	529	49	0.09	33
1989	199	97	22	22.7	185	38	0.10	377	204	35	0.2	677	59	0.09	25
1990	260	93	23	24.7	272	99	0.18	549	240	35	0.1	949	73	0.08	68
1991	319	234	47	20.1	369	56	0.08	560	474	64	0.1	953	65	0.07	72
1992															
1993	238	270	27	10.0	555	105	0.10	420	531	45	0.1	1,213	73	0.06	57
1994															
1995	325	341	41	12.0		101	0.08	677	731	66	0.1	1,587	72	0.05	36
1996															
1997															
1998															
1999	500	588	55	9.4	1,150	161	0.07	711	798	82	0.1	1,485	73	0.05	67

Table 1 (continued)

	Yellowstone Cutthroat trout							Rainbow Trout							
Year	M	C	R	R/C	YCT/km	SD	CV	M	C	R	R/C	RBT/km	SD	CV	Mean Q (cms)
2000															
2001															
2002	108	138	14	10.1	246	65	0.13	4	3	1					98
2003	90	81	11	13.6	237	133	0.29	2	2	0					81
2004															
2005	37	47	4	8.5	76	54	0.36	5	2	0					78
2006	112	71	14	19.7	116	25	0.11	10	12	1					
2007	90	41	2	4.9				17	6	0					131
2008	30	34	0	0.0				2	2	0					157
2009	77	110	10	9.1	218	93	0.22	13	10	1					92
2010	110	91	10	11.0	233	83	0.18	8	11	1					91
2011	134	126	12	9.5	279	132	0.24	12	17	0					107
2012	134	106	10	9.4	321	93	0.15	5	11	0					93
2013	150	167	25	15.0	299	72	0.12	17	27	0					66
2014	97	98	21	21.4	117	27	0.12	20	14	1					93
2015	77	109	5	4.6	298	206	0.35	8	21	0					110
2016	171	135	23	17.0	213	41	0.10	14	24	2					86
2017	152	193	36	18.7	184	29	0.08	21	28	4	14.3	26	17	0.33	67
2018	121	186	17	9.1	286	76	0.14	14	26	0					108

	Brown Trout							Total trout							
Year	M	C	R	R/C	BNT/km	SD	CV	M	C	R	R/C	trout/km	SD	CV	Mean Q (cms)
2000															
2001															
2002	457	579	61	10.5	1,030	117	0.06	582	750	76	0.1	1,385	65	0.05	98
2003	557	432	61	14.1	926	110	0.06	668	593	72	0.1	1,184	60	0.05	81
2004															
2005	440	486	67	13.8	771	91	0.06	641	569	71	0.1	2,030	155	0.08	78
2006	1,154	933	140	15.0	1,761	148	0.04	1,326	1,064	155	0.1	2,116	76	0.04	
2007	764	446	67	15.0	1,125	110	0.05	888	525	69	0.1	1,504	69	0.05	131
2008	373	365	40	11.0	778	132	0.09	415	418	40	0.1	988	76	0.08	157
2009	603	739	104	14.1	915	90	0.05	718	916	117	0.1	1,236	52	0.04	92
2010	600	545	110	20.2	653	49	0.04	735	709	121	0.2	956	33	0.03	91
2011	323	365	27	7.4	1,058	241	0.12	495	544	39	0.1	1,770	150	0.08	107
2012	437	435	51	11.7	784	99	0.06	607	642	61	0.1	1,329	64	0.05	93
2013	838	714	108	15.1	1,200	121	0.05	1,094	1,041	140	0.1	1,826	68	0.04	66
2014	589	481	72	15	854	90	0.05	761	624	95	0.2	1,203	47	0.04	93
2015	423	558	70	12.5	730	131	0.09	571	986	80	0.1	1,326	70	0.05	110
2016	787	753	95	12.6	1,349	136	0.05	1,122	1,125	126	0.1	2,309	80	0.03	86
2017	757	794	152	19.1	892	69	0.04	930	1,015	192	0.2	1,175	40	0.03	67
2018	293	458	44	9.6	653	124	0.1	429	675	61	0.1	1,014	122	0.06	108

Table 2. Summary statistics from the Conant monitoring site between 1982 and 2018 on the South Fork Snake River, including number of fish marked (M), number of fish captured C, number of fish recaptured R, capture efficiency (R/C), linear estimates for Yellowstone Cutthroat Trout (YCT), Rainbow Trout (RBT), Brown Trout (BNT), and all trout species combined. Standard deviations (SD) and coefficients of variation (CV) are also included for each estimate, and the average river flows (mean Q) during the sampling period are reported.

	Yellowstone Cutthroat Trout							Rainbow Trout							
Year	M	C	R	R/C	YCT/km	SD	CV	M	C	R	R/C	RBT/km	SD	CV	Mean Q (cms)
1982					1,899							16			
1983															
1984															
1985															
1986	1,170	546	70	12.8	2,890	402	0.07	32	16	2	12.5				102
1987	281							5							26
1988	1,100	561	98	17.5	1,491	148	0.05	41	18	1	5.6				103
1989	1,416	1,050	200	19.0	1,610	108	0.03	57	55	10	18.2	102	42	0.21	86
1990	1,733	1,522	317	20.8	2,330	173	0.04	113	109	14	12.8	330	104	0.16	101
1991	1,145	625	140	22.4	1,399	136	0.05	98	54	9	16.7	216	87	0.20	132
1992	595							34							60
1993	972	623	100	16.1	1,512	150	0.05	74	41	6	14.6	177	82	0.24	91
1994	853							87							52
1995	631	542	77	14.2	1,230	147	0.06	130	140	17	12.1	436	116	0.14	93
1996	707	548	72	13.1	1,502	225	0.08	155	111	5	4.5	958	677	0.36	107
1997	910	895	164	18.3	1,145	76	0.03	429	467	72	15.4	974	118	0.06	85
1998	674	682	61	8.9	1,691	204	0.06	216	247	26	10.5	743	127	0.09	110
1999	1,019	883	117	13.3	1,847	163	0.04	345	241	29	12.0	1,055	204	0.10	110

	Brown Trout							Total trout							
Year	M	C	R	R/C	BNT/km	SD	CV	M	C	R	R/C	trout/km	SD	CV	Mean Q (cms)
1982					412										
1983															
1984															
1985															
1986	183	105	8	7.6	641	253	0.20	1,385	667	80	0.12	2,351	236	0.10	102
1987	26							312							26
1988	113	46	4	8.7	340	310	0.47	1,254	625	103	0.16	1,836	88	0.05	103
1989	92	76	11	14.5	191	162	0.43	1,565	1,181	221	0.19	1,791	54	0.03	86
1990	173	117	12	10.3	369	133	0.18	2,019	1,748	343	0.20	2,984	89	0.03	101
1991	150	119	19	16.0	195	52	0.14	1,393	798	168	0.21	1,616	58	0.04	132
1992	76							705							60
1993	101	64	10	15.6	135	78	0.29	1,147	728	116	0.16	1,643	66	0.04	91
1994	110							1,050							52
1995	150	108	13	12.0	294	176	0.31	911	790	107	0.14	1,696	79	0.05	93
1996	212	124	18	14.5	314	78	0.13	1,074	783	95	0.12	2,292	131	0.06	107
1997	344	281	82	29.2	369	203	0.28	1,683	1,643	318	0.19	1,969	48	0.02	85
1998	257	216	49	22.7	249	36	0.07	1,147	1,145	136	0.12	2,191	79	0.04	110
1999	293	241	31	12.9	512	169	0.17	1,657	1,365	177	0.13	2,827	90	0.03	110

Table 2 (continued)

	Yellowstone Cutthroat Trout							Rainbow Trout							
Year	M	C	R	R/C	YCT/km	SD	CV	M	C	R	R/C	RBT/km	SD	CV	Mean Q (cms)
2000	797							260							91
2001	776							321							117
2002	495	394	50	12.7	841	119	0.07	295	257	24	9.3	1,265	314	0.13	72
2003	422	571	72	12.6	840	119	0.07	272	360	29	8.1	1,501	364	0.12	108
2004	315	379	51	13.5	478	61	0.07	227	304	29	9.5	854	168	0.10	114
2005	391	254	30	11.8	658	205	0.16	172	142	11	7.7	678	340	0.26	106
2006	423	365	54	14.8	749	104	0.07	289	251	23	9.2	1,092	287	0.13	89
2007	784	568	72	12.7	1,380	142	0.05	565	361	52	14.4	1,329	182	0.07	116
2008	377	554	51	9.2	1,065	156	0.07	187	318	25	7.9	925	174	0.10	170
2009	623	489	90	18.4	826	87	0.05	475	425	34	8.0	2,270	486	0.11	98
2010	389	307	27	8.8	1,211	284	0.12	286	139	7	5.0	1,893	1,073	0.29	127
2011	609	429	70	16.3	1,225	221	0.09	448	311	28	9.0	1,190	256	0.11	99
2012	721	601	102	17.0	1,059	104	0.05	445	518	44	8.49	1,198	177	0.08	105
2013	784	536	73	13.6	1,401	159	0.06	578	393	52	13.2	1,180	334	0.14	62
2014	488	415	50	12.1	923	132	0.07	350	265	28	10.6	880	172	0.10	77
2015	613	496	63	12.7	1,069	127	0.06	447	330	49	14.9	653	84	0.07	85
2016	717	673	135	20.1	900	73	0.04	639	556	103	18.5	803	76	0.05	101
2017	777	723	158	21.9	883	70	0.04	855	686	116	16.9	1,147	108	0.05	111
2018	779	425	70	14.7	1,137	127	0.05	881	519	53	10.2	1,907	249	0.07	115

	Brown Trout							Total trout							
Year	M	C	R	R/C	BNT/km	SD	CV	M	C	R	R/C	trout/km	SD	CV	Mean Q (cms)
2000	133							1,190							91
2001	208							1,305							117
2002	111	104	9	8.7	288	122	0.22	901	755	83	11.0	1,803	81	0.05	72
2003	143	165	27	16.4	240	99	0.21	837	1,096	128	11.7	1,821	67	0.04	108
2004	169	202	22	10.9	383	204	0.27	711	885	102	11.5	1,441	62	0.04	114
2005	115	95	10	10.5	206	105	0.26	678	491	51	10.4	1,588	200	0.13	106
2006	215	223	31	13.9	329	70	0.11	927	839	108	12.9	1,938	80	0.04	89
2007	404	289	50	17.3	530	117	0.11	1,753	1,218	174	14.3	2,713	87	0.03	116
2008	205	253	29	11.5	380	57	0.08	769	1,125	105	9.3	1,882	74	0.04	170
2009	261	219	42	19.2	307	48	0.08	1,359	1,133	166	14.7	2,276	80	0.04	98
2010	178	154	14	9.1	479	136	0.15	853	600	48	8.0	2,295	297	0.13	127
2011	357	300	29	9.7	796	166	0.11	1,414	1,040	127	12.2	3,002	142	0.05	99
2012	561	573	75	13.1	892	111	0.06	1,827	1,776	221	12.4	3,543	95	0.03	105
2013	538	314	52	16.6	752	212	0.14	1,947	1,319	179	13.6	3,136	123	0.04	62
2014	382	273	46	16.9	475	60	0.06	1,276	981	124	12.6	2,473	92	0.04	77
2015	440	295	37	12.5	779	196	0.13	1,670	1,313	156	11.9	3,168	107	0.03	85
2016	608	458	96	21.0	628	55	0.04	2,176	1,850	336	18.2	3,270	83	0.03	101
2017	688	565	145	25.7	573	55	0.05	2,320	1,974	419	21.2	2,697	53	0.02	111
2018	436	298	33	11.1	836	129	0.08	2,123	1,304	156	12.0	3,915	263	0.03	115

Table 3. Summary statistics from the Lufkin monitoring site for 2014 and 2018 on the South Fork Snake River, including number of fish marked (M), number of fish captured C, number of fish recaptured R, capture efficiency (R/C), linear estimates for Yellowstone Cutthroat Trout (YCT), Rainbow Trout (RBT), Brown Trout (BNT), and all trout species combined. Standard deviations (SD) and coefficients of variation (CV) are also included for each estimate, and the average river flow (mean Q) during the sampling period is reported.

	Yellowstone Cutthroat Trout							Rainbow Trout							
Year	M	C	R	R/C	YCT/km	SD	CV	M	C	R	R/C	RBT/km	SD	CV	Mean Q (cms)
2014	264	215	15	7.0	1,497	441	0.15	147	107	13	12.2	364	122	0.17	161
2015	376	365	54	14.8	1,065	165	0.08	242	169	25	14.8	616	152	0.13	165
2016	348	351	67	19.1	618	78	0.06	159	168	21	12.5	455	207	0.23	63
2018	279	363	32	8.8	1,064	167	0.08	217	235	24	10.2	861	216	0.13	219

	Brown Trout							Total trout							
Year	M	C	R	R/C	BNT/km	SD	CV	M	C	R	R/C	trout/km	SD	CV	Mean Q (cms)
2014	245	191	18	9.4	820	211	0.13	665	520	46	8.8	2,428	104	0.04	161
2015	191	201	27	13.4	439	95	0.11	848	797	108	13.6	2,285	66	0.03	165
2016	216	299	26	8.7	730	242	0.17	734	855	115	13.0	1,711	60	0.04	63
2018	315	255	31	12.2	814	154	0.10	813	858	87	10.1	2,696	271	0.05	219

Table 4. Estimated annual angling effort on the South Fork Snake River between 1979 and 2017, with average trip durations, categorization of angler type, and terminal tackle used.

Year	Total effort (h)	Average time per trip (h/d)	Effort by angler type (h)		Bait (%)	Lure (%)	Fly (%)
			Boat	Bank			
1979	88,830	NA	41,750	47,080	48	19	33
2003	216,181	4.9	170,783	45,398	15	13	71
2005	233,009	3.8	188,737	44,272	17	14	68
2012	385,153	3.7	331,347	53,804	13	16	71
2017	258,249	5.1	202,188	56,061	17	11	72

Table 5. Percentages of the total catch and total harvest by boat and bank anglers in the South Fork Snake River between 1979 and 2017.

Year	Catch composition (%)		Harvest composition (%)	
	Boat	Bank	Boat	Bank
1979	57	43	47	53
2003	77	23	50	50
2005	75	25	56	44
2012	81	19	42	58
2017	91	9	31	69

Table 6. Total annual catch and harvest on the South Fork Snake River from April 2017 through March 2018 in the three river sections for Yellowstone Cutthroat Trout (YCT), Rainbow Trout (RBT), Brown Trout (BNT), and Mountain Whitefish (MWF).

Section	Catch				Harvest			
	YCT	RBT	BNT	MWF	YCT	RBT	BNT	MWF
Upper	52,902	33,601	18,706	19,981	21	6,822	426	0
Canyon	74,129	31,999	43,473	43,473	31	1,618	108	7
Lower	8,536	2,416	2,591	2,591	0	227	163	14
	Catch				Harvest			
Section	YCT	RBT	BNT	MWF	YCT	RBT	BNT	MWF
Upper	42%	27%	15%	16%	0.3%	94%	60%	0%
Canyon	40%	17%	19%	24%	20%	92%	60%	0%
Lower	38%	11%	40%	11%	0%	56%	40%	3%

Table 7. The composition of annual catch and annual harvest in the South Fork Snake River during creel surveys conducted from 2003 through 2017 according to terminal tackle used.

	Catch composition (%)				Harvest composition (%)			
Year	Bait	Lures	Flies	Combo	Bait	Lures	Flies	Combo
2003	14	12	68	6	43	20	26	11
2005	15	15	62	8	40	19	28	14
2012	5	13	73	9	14	28	39	19
2017	7	5	84	4	40	11	36	13

Table 8. Total annual catch and harvest of fish in the South Fork Snake River during creel surveys conducted from 1982 through 2017.

	Yellowstone Cutthroat Trout		Rainbow Trout		Brown Trout		Mountain Whitefish		Sucker sp.	
Annual Totals	Catch	Harvest	Catch	Harvest	Catch	Harvest	Catch	Harvest	Catch	Harvest
1979										
1982	32,456	17,603	477	585	4,295	3,404	9,546	5,631	955	627
1996	134,182	2,484	13,229	894	22,679	1,132	18,899	0	1,890	126
2003	43,898	104	18,397	4,560	19,217	1,508	8,743	146	820	15
2005	41,411	0	14,763	3,414	14,112	666	19,353	98	34	0
2012	116,450	114	85,451	28,282	168,596	15,006	37,490	352	5,014	0
2017	135,668	51	68,458	8,750	62,197	697	66,309	23	1,095	0

Table 9. South Fork Snake River tributary weir summary statistics from 2001 through 2018.

Location and year	Weir type	Operation dates	Estimated weir efficiency (%)[a]	Catch: Cutthroat Trout	Catch: Rainbow Trout	Catch: Total
Burns Creek						
2001[b]	Floating panel	March 7 - July 20	16	3,156	3	3,159
2002[b]	Floating panel	March 23 - July 5	NE[c]	1,898	46	1,944
2003[d]	Floating panel	March 28 - June 23	17-36	1,350	1	1,351
2004	ND[e]	ND	ND	ND	ND	ND
2005	ND	ND	ND	ND	ND	ND
2006	Mitsubishi	April 14 - June 30	NE	1,539		
2007	ND	ND	ND	ND	ND	ND
2008	ND	ND	ND	ND	ND	ND
2009	Fall/velocity	Apirl 9 - July 22	98	1,491	2	1,493
2010	Fall/velocity	March 26 - July 14	100	1,550	2	1,552
2011	Fall/velocity	March 23 - July 12	90	891	5	896
2012	Fall/velocity	March 24 - July 11	90	496	0	496
2013	Fall/velocity	April 4 - July 2	98	888	6	894
2014	Fall/velocity	April 1 - July 3	90	833	12	845
2015	Fall/velocity	April 6 - July 3	94	1,357	1	1,358
2016	Fall/velocity	April 4 - July 3	98	1,528	7	1,535
2017	Fall/velocity	April 1 - June 27	87	759	4	763
2018	Fall/velocity	April 3 - July 6	100	1,303	9	1,312
Pine Creek						
2001[b]	ND	ND	ND	ND	ND	ND
2002[b]	Floating panel	April 2 - July 5	NE	202	14	216
2003[f]	Floating panel	March 27 - June 12	40	328	7	335
2004	Hard picket	March 25 - June 28	98	2,143	27	2,170
2005	Hard picket	April 6 - June 30	NE	2,817	40	2,857
2006[g]	Mitsubishi	April 14 - April 18	NE	NE	NE	NE
2007	Mitsubishi	March 24 - June 30	20	481	2	483
2008	Hard picket	April 21 - July 8	NE	115	0	115
2009	Hard picket	Apirl 6 - July 15	49	1,356	1	1,357
2010	Electric	April 13 - July 6	NE	2,972	3	2,975
2011	Electric	April 11 - July 9	49	1,509	1	1,510
2012	Electric	March 28 - July 1	NE	1,427	3	1,430
2013	Electric	April 5 - June 22	89	1,908	1	1,909
2014	Electric	April 7- June 30	70	899	7	906
2015	Electric	April 1 - June 25	78	1,864	3	1,867
2016	Electric	April 1- June 22	93	3,240	8	3,248
2017	Electric	April 3 - June 26	67	2,695	2	2,697
2018	Electric	April 2 - June 26	94	2,075	6	2,081

[a]Weir efficiency was estimated using several different methods
[b]From Host (2003)
[c]NE = no estimate
[d]Weir was shut down on June 10, but the trap was operated until June 23
[e]ND = no data; weir either not built or not operated
[f]Weir was shut down early due to high cutthroat trout mortality
[g]Weir was destroyed during high runoff

Table 9 (continued)

Location and year	Weir type	Operation dates	Estimated weir efficiency (%)[a]	Catch: Cutthroat Trout	Catch: Rainbow Trout	Catch: Total
Rainey Creek						
2001[b]	Floating panel	March 7 - July 6	NE	0	0	0
2002[b]	Floating panel	March 26 - June 27	NE	1	0	1
2003	ND	ND	ND	ND	ND	ND
2004	ND	ND	ND	ND	ND	ND
2005	Hard picket	April 7 - June 29	NE	25	0	25
2006	Hard picket	April 5 - June 30	NE	69	3	72
2007	Hard picket	March 19 - June 30	NE	14	0	14
2008	Hard picket	June 19 - July 11	NE	14	0	14
2009	Hard picket	April 7 - July 6	NE	23	0	23
2010	Hard picket	April 13 - June 29	NE	145	1	146
2011	Electric	March 28 - June 28	NE	0	0	0
2012	Electric	April 18 - June 23	NE	7	0	7
2013	Electric	ND	ND	ND	ND	ND
2014	Electric	April 29 - June 25	NE	56	2	58
2015	Electric	April 2 - June 21	NE	73	2	75
2016	Electric	April 1 - June 23	NE	19	2	21
2017	Electric	April 3 - June 26	NE	37	2	39
2018	Electric	April 2 - June 26	NE	37	0	37
2019	Electric	April 8 - June 24	NE	70	0	70
Palisades Creek						
2001[b]	Floating panel	March 7 - July 20	10	491	160	651
2002[b]	Floating panel	March 22 - July 7	NE	967	310	1,277
2003	Floating panel	March 24 - June 24	21 - 47	529	181	710
2004	ND	ND	ND	ND	ND	ND
2005	Mitsubishi	March 18 - June 30	91	1,071	301	1,372
2006	Mitsubishi	April 4 - June 30	13	336	52	388
2007	Electric	May 1 - July 28	98	737	20	757
2008	ND	ND	NE	ND	ND	ND
2009	Electric	May 12 - July 20	26	202	4	206
2010	Electric	March 19 - July 18	86	545	50	595
2011	Electric	April 7 - June 15	NE	30	13	43
2012	Electric	March 24 - July 2	88	232	20	252
2013	Electric	April 5 - July 8	96	619	23	642
2014	Electric	April 2 - July 18	98	734	63	797
2015	Electric	April 2 - July 18	95	832	14	846
2016	Electric	April 1 - July 6	99	958	27	985
2017	Electric	April 3 - July 21	100	755	63	818
2018	Electric	April 2 - July 10	92	478	18	496

[a]Weir efficiency was estimated using several different methods
[b]From Host (2003)

Figure 1. Location of Warm Springs Creek near the mouth of Burns Creek in the South Fork Snake River drainage.

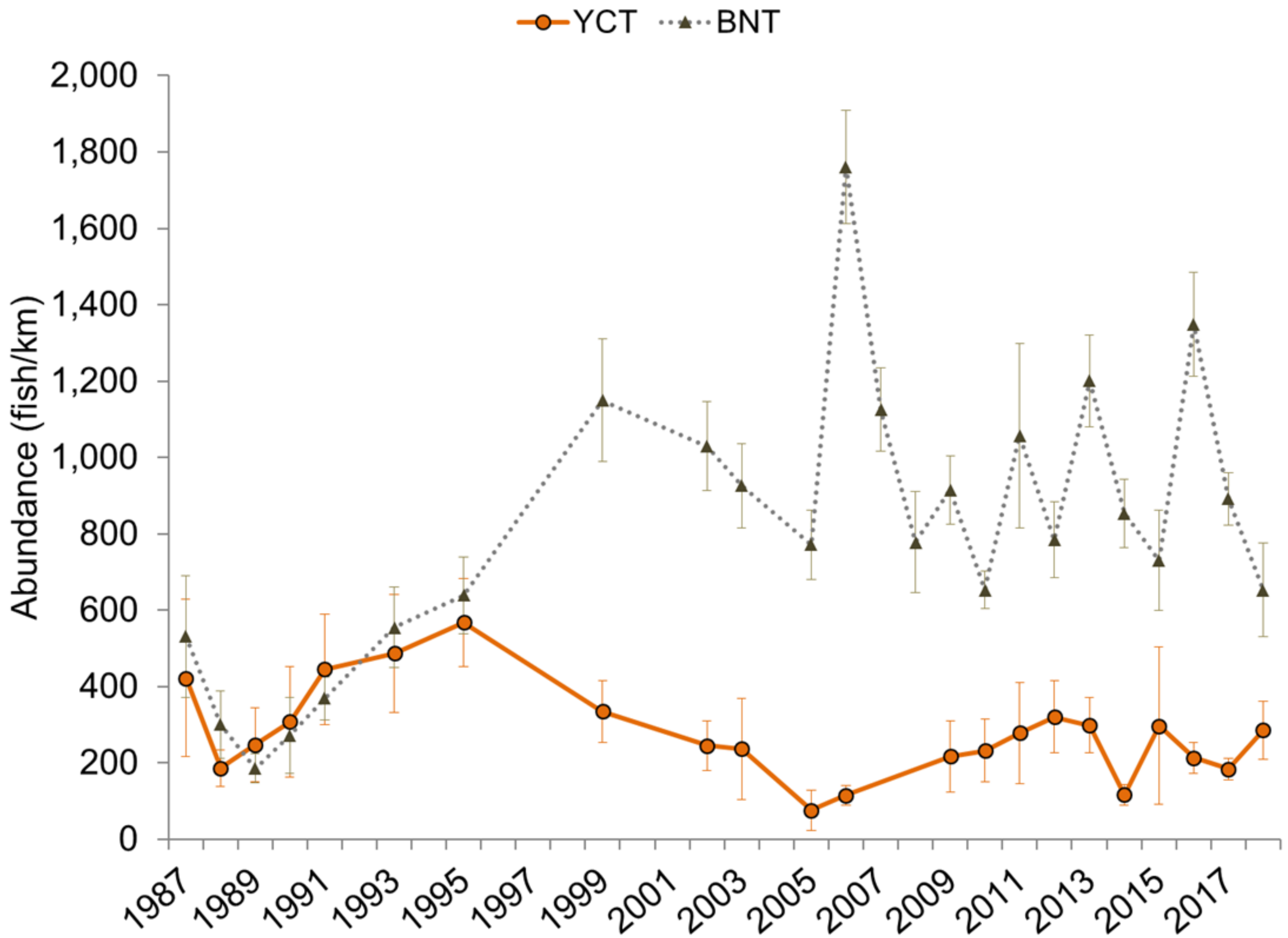

Figure 2. Abundance estimates and 95% confidence intervals for Yellowstone Cutthroat Trout (YCT) and Brown Trout (BNT) at the Lorenzo monitoring reach on the South Fork Snake River from 1987 through 2018.

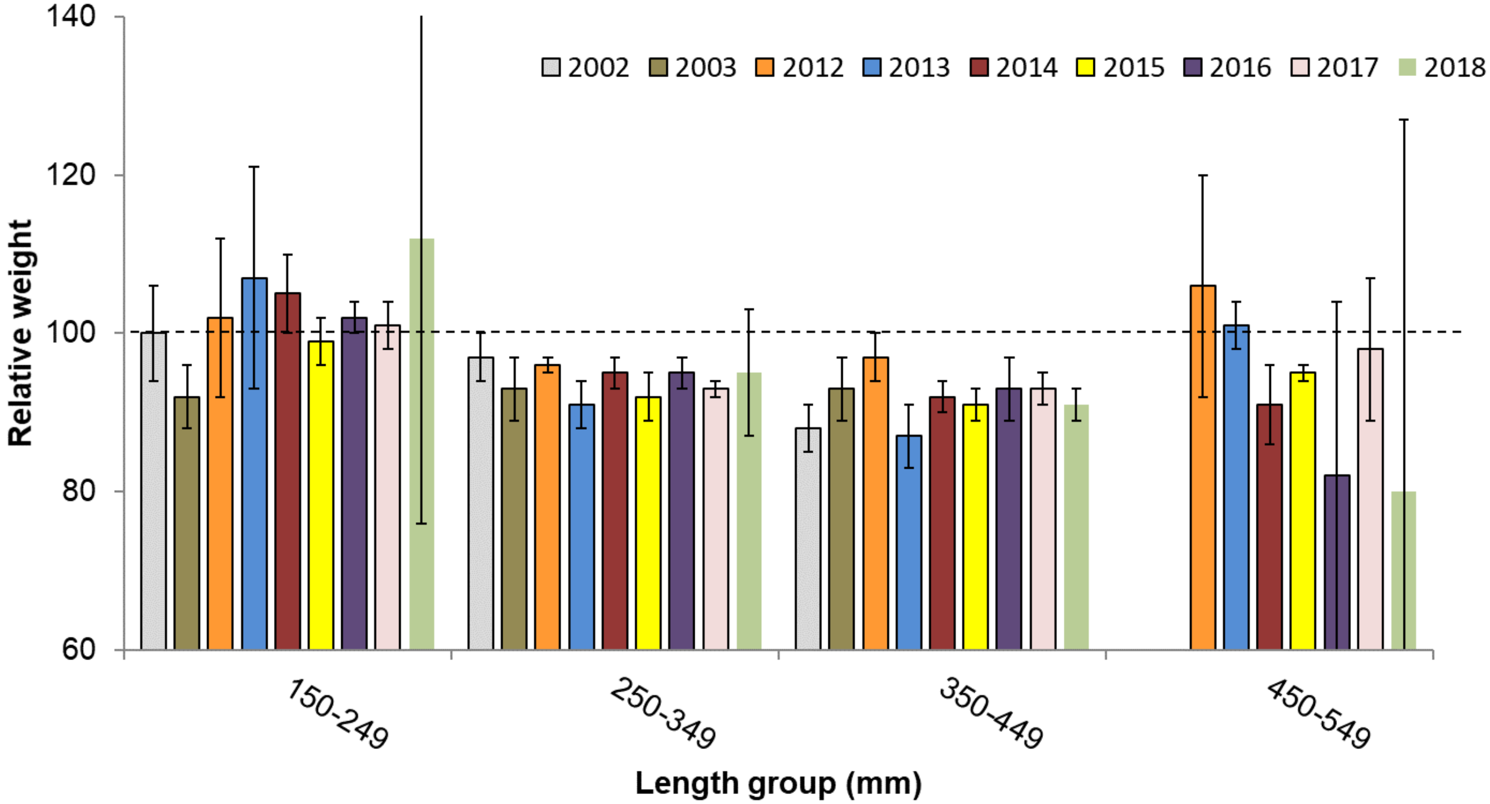

Figure 3. Relative weights and 95% confidence intervals for Yellowstone Cutthroat Trout at the Lorenzo monitoring reach on the South Fork Snake River from 2002 through 2018.

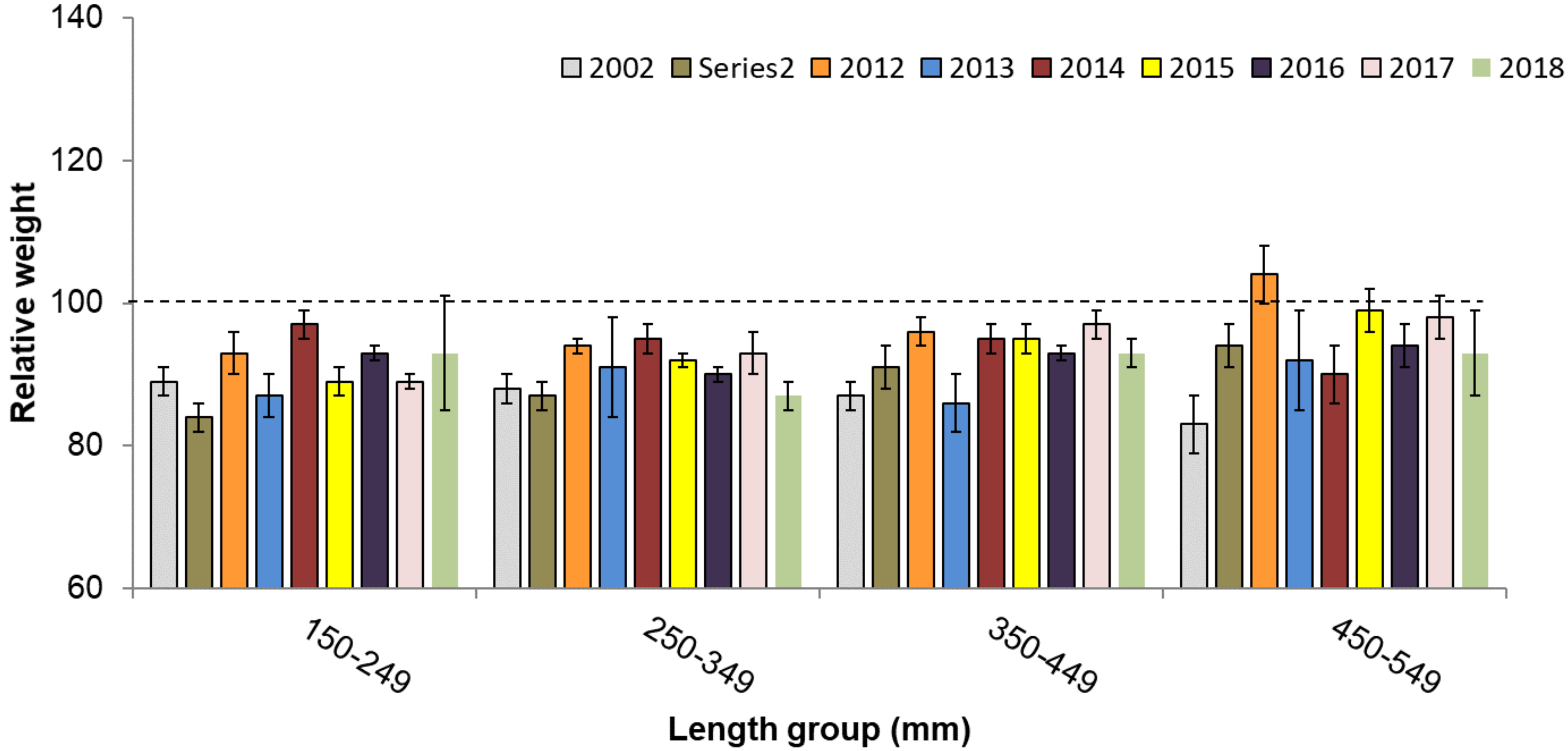

Figure 4. Relative weights and 95% confidence intervals for Brown Trout at the Lorenzo monitoring reach on the South Fork Snake River from 2002 through 2018.

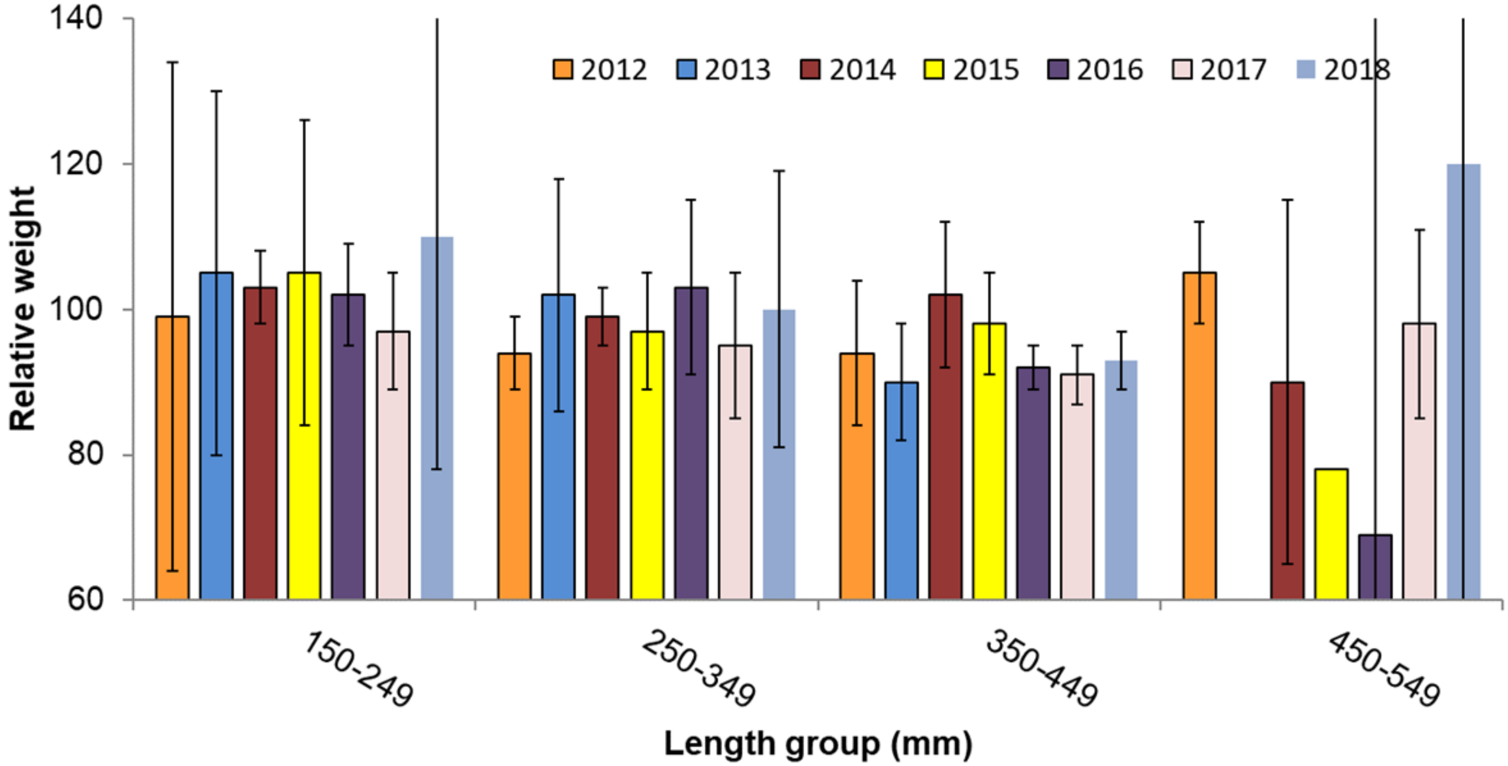

Figure 5. Relative weights and 95% confidence intervals for Rainbow Trout at the Lorenzo monitoring reach on the South Fork Snake River from 2012 through 2018.

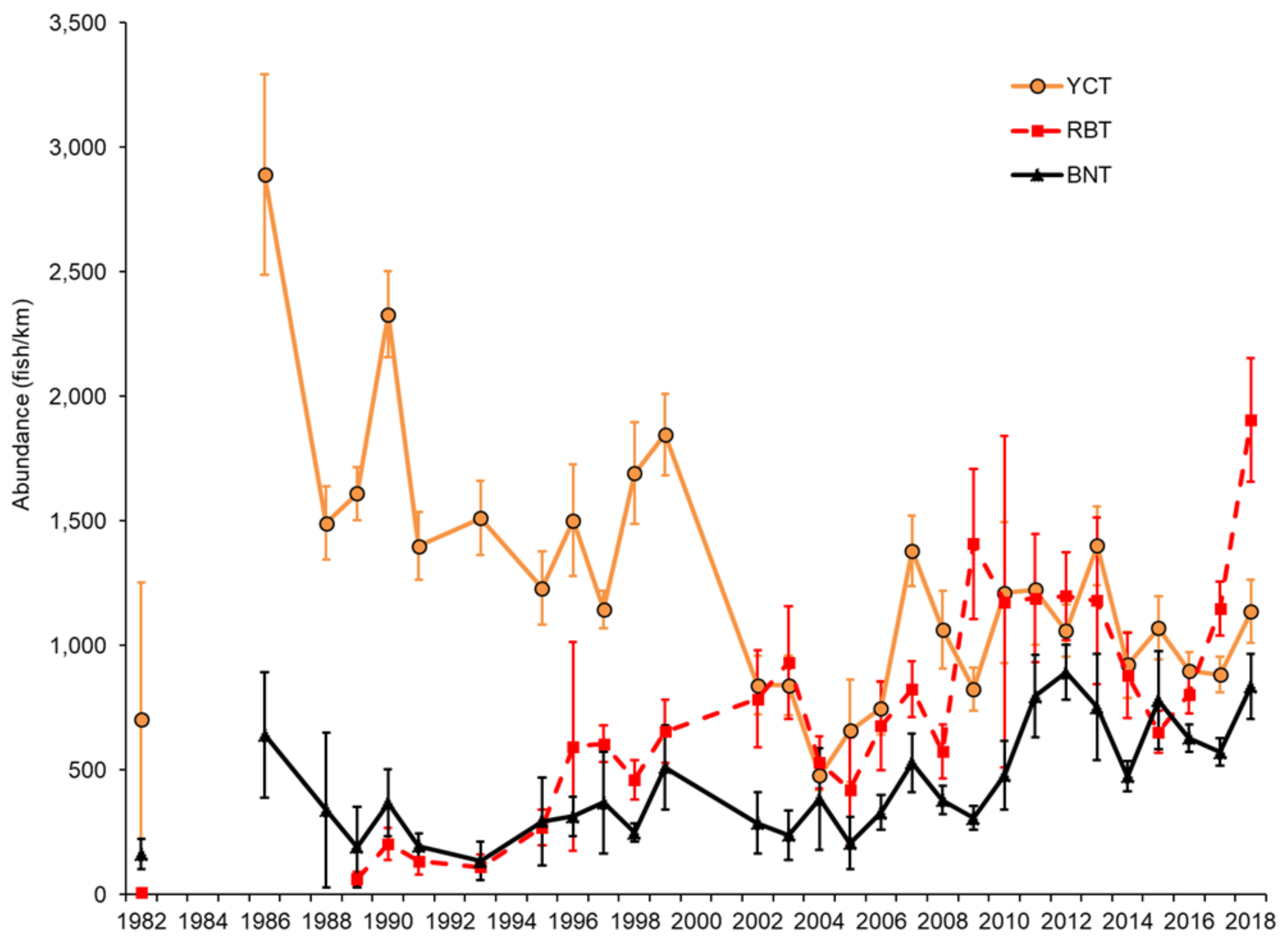

Figure 6. Abundance estimates and 95% confidence intervals for Yellowstone Cutthroat Trout (YCT), Rainbow Trout (RBT), and Brown Trout (BNT) at the Conant monitoring reach on the South Fork Snake River from 1982 through 2018.

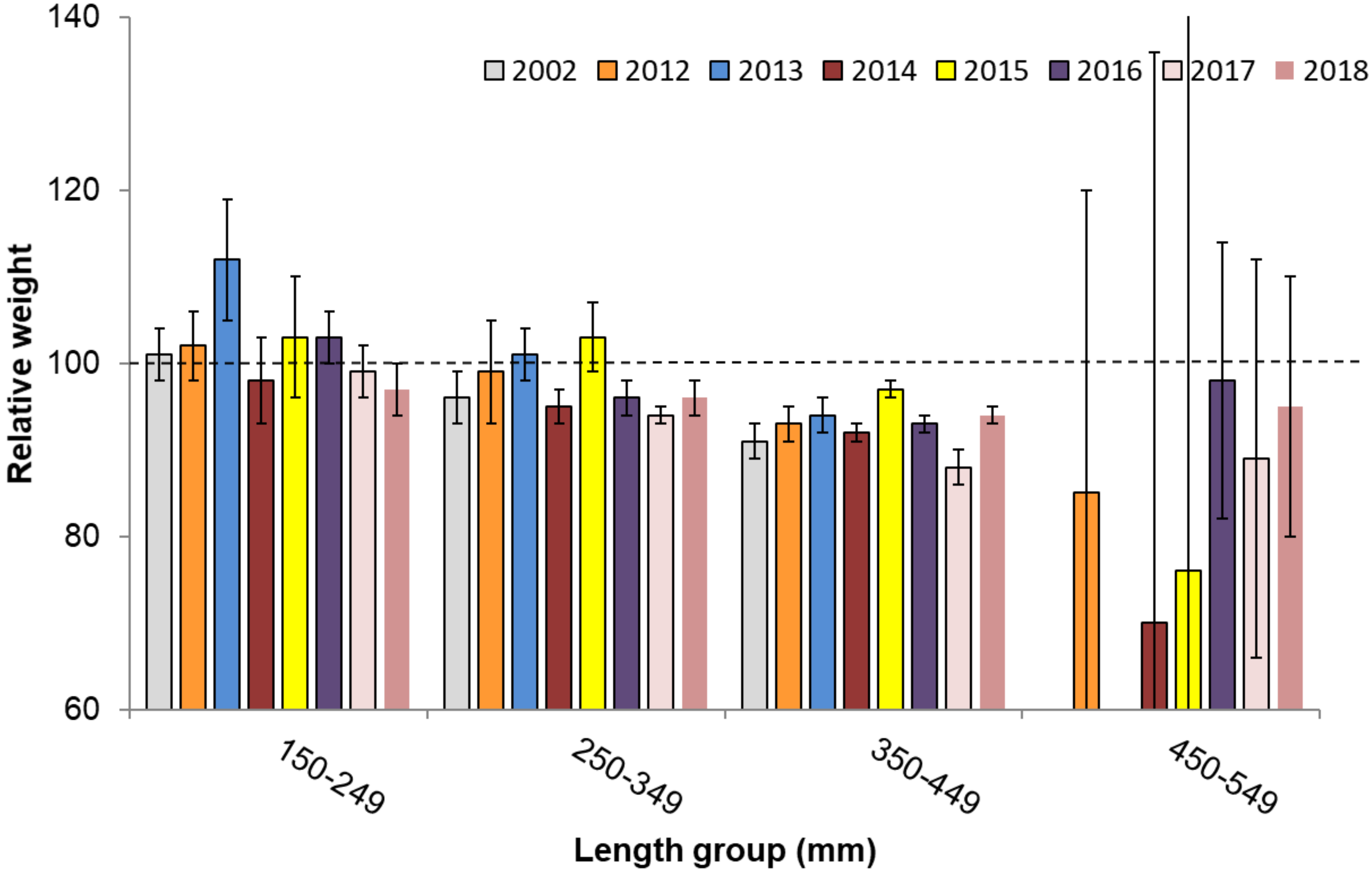

Figure 7. Relative weights and 95% confidence intervals for Yellowstone Cutthroat Trout at the Conant monitoring reach on the South Fork Snake River from 2002 through 2018.

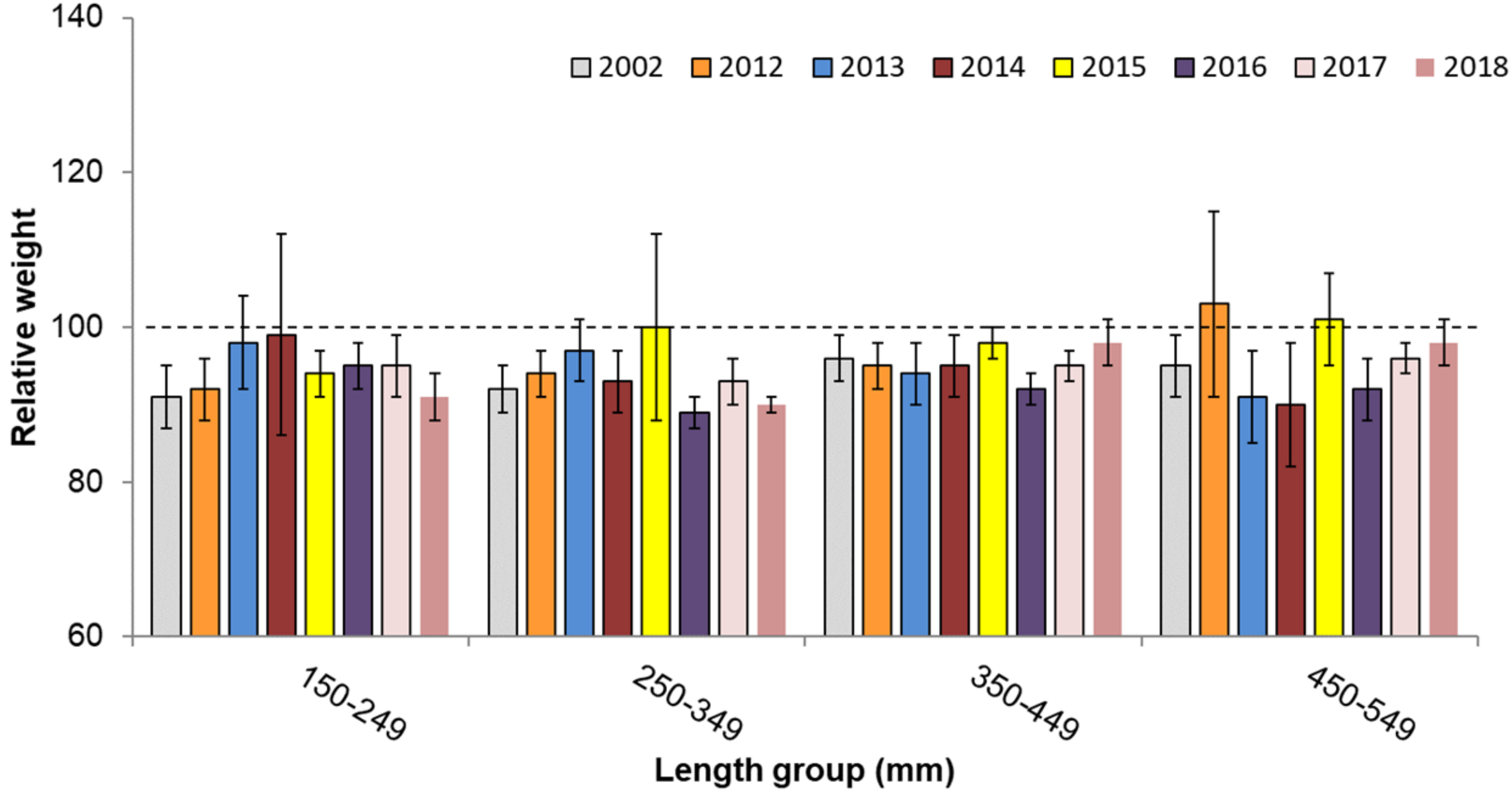

Figure 8. Relative weights and 95% confidence intervals for Brown Trout at the Conant monitoring reach on the South Fork Snake River from 2002 through 2018.

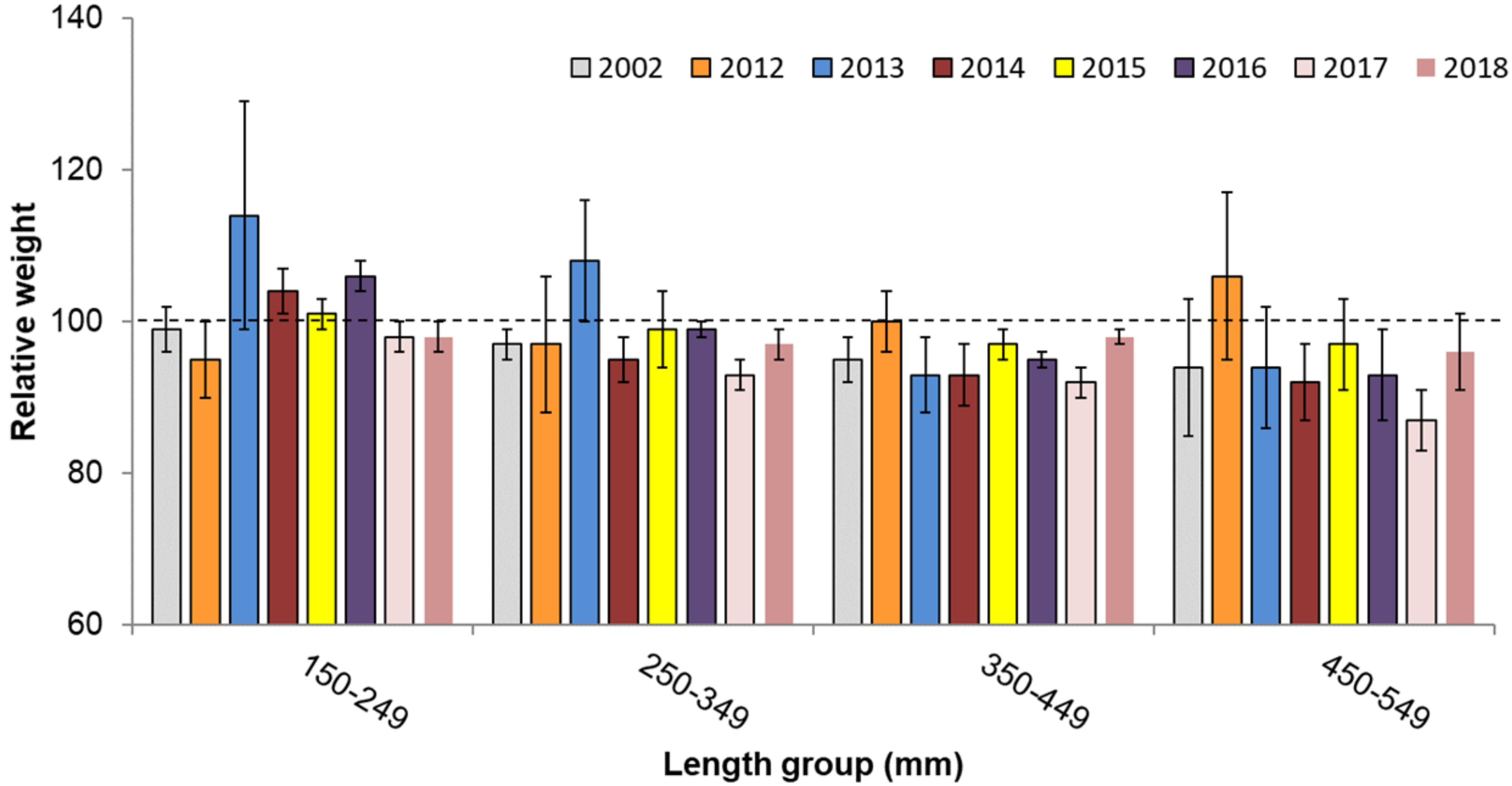

Figure 9. Relative weights and 95% confidence intervals for Rainbow Trout at the Conant monitoring reach on the South Fork Snake River from 2002 through 2018.

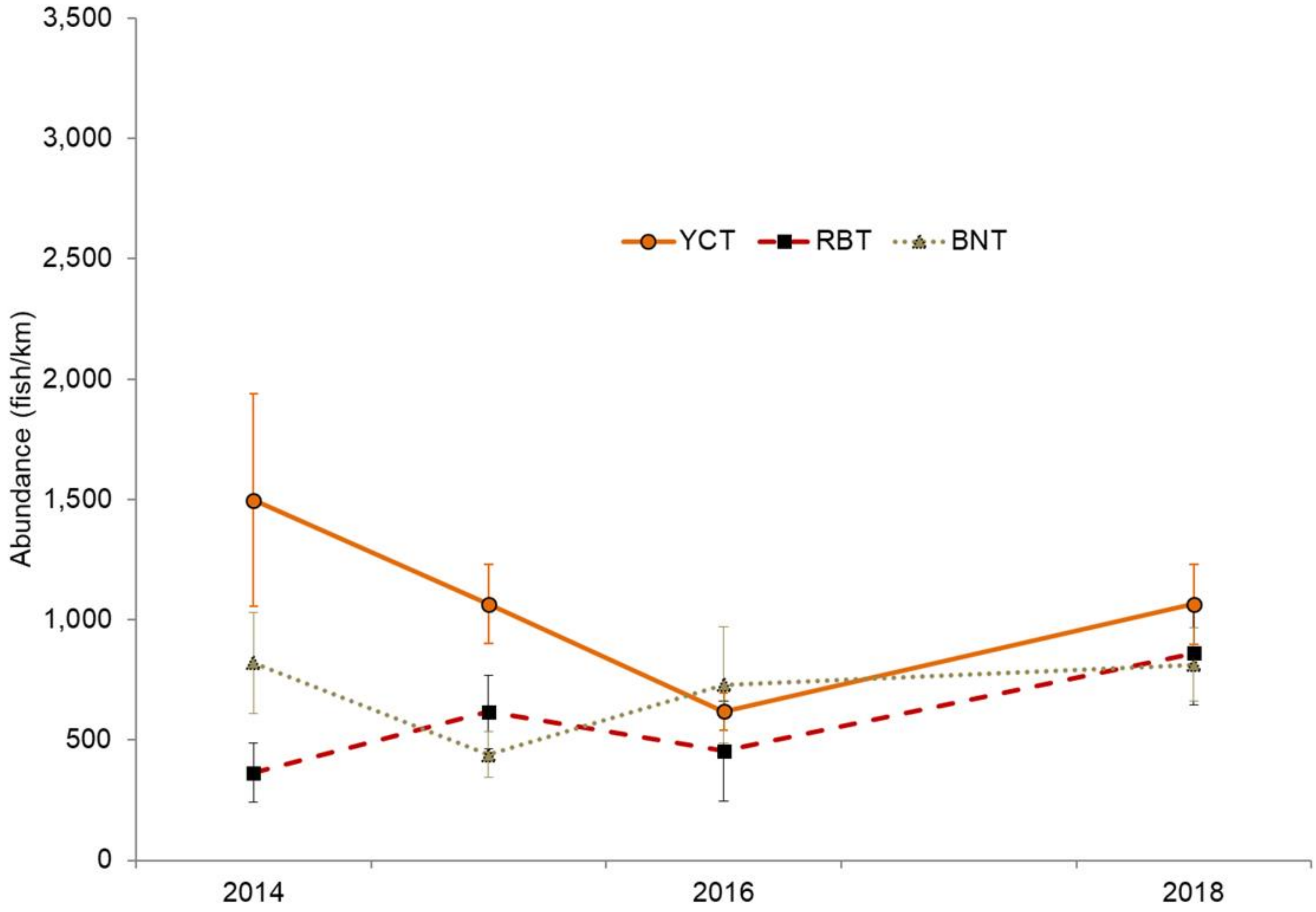

Figure 10. Abundance estimates and 95% confidence intervals for Yellowstone Cutthroat Trout (YCT), Rainbow Trout (RBT), and Brown Trout (BNT) at the Lufkin monitoring reach on the South Fork Snake River from 2014 through 2018.

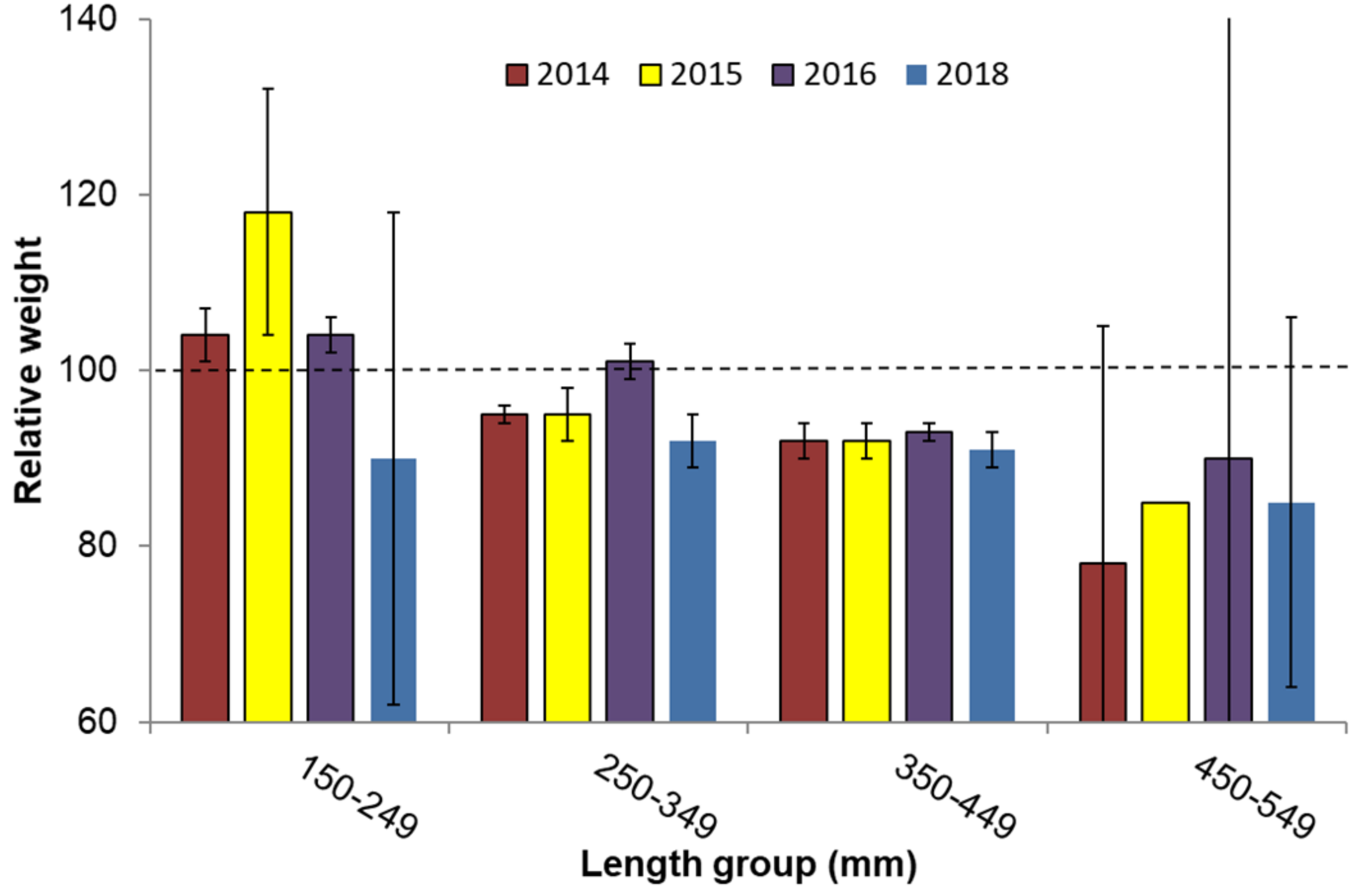

Figure 11. Relative weights and 95% confidence intervals for Yellowstone Cutthroat Trout at the Lufkin monitoring reach on the South Fork Snake River from 2014 through 2018.

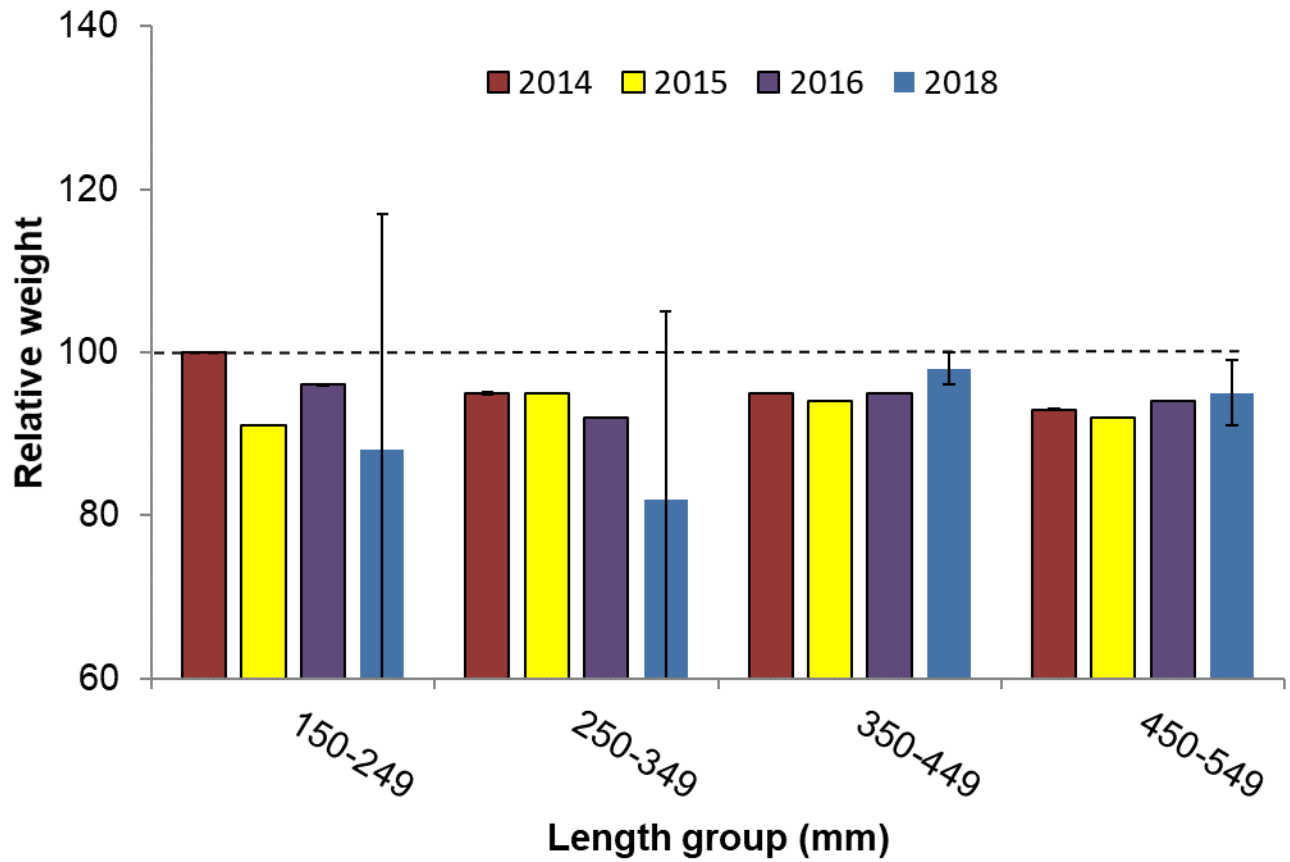

Figure 12. Relative weights and 95% confidence intervals for Brown Trout at the Lufkin monitoring reach on the South Fork Snake River from 2014 through 2018.

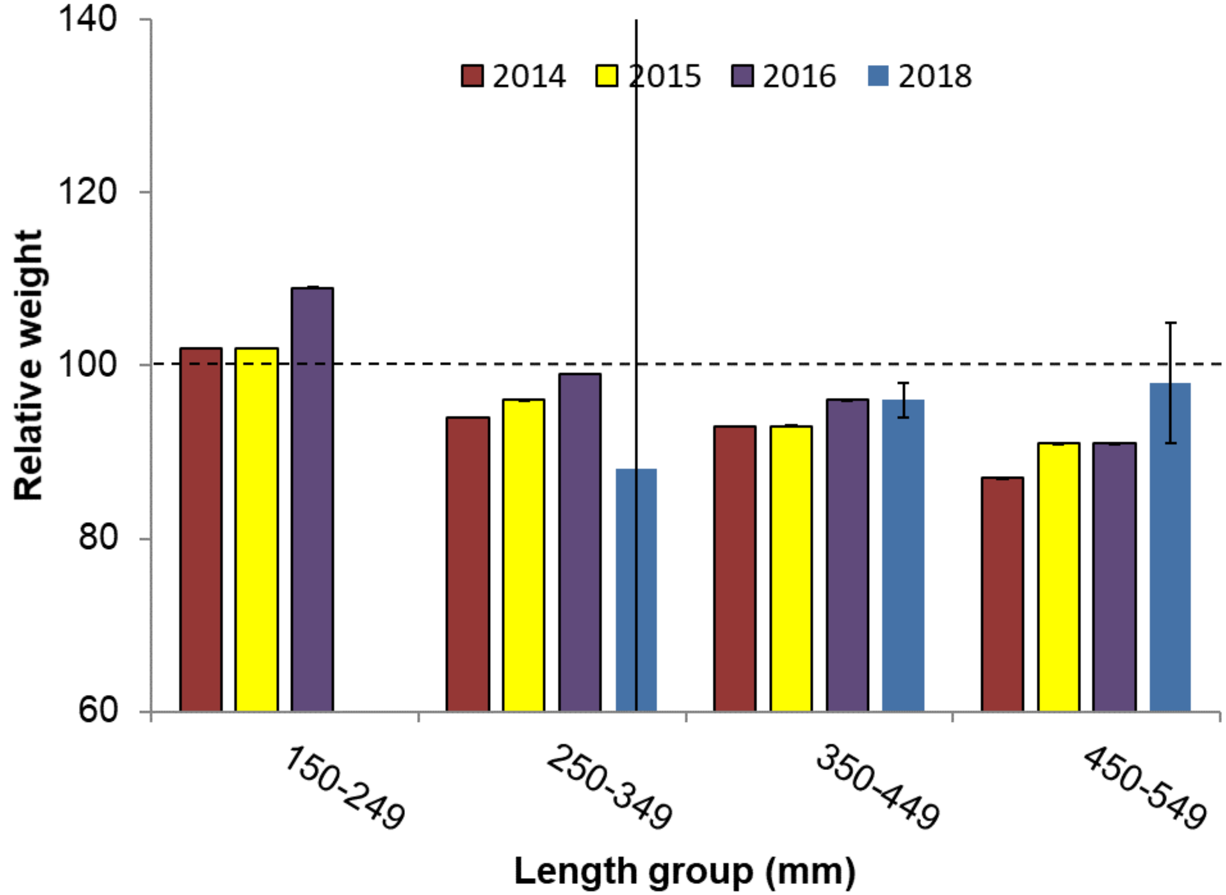

Figure 13. Relative weights and 95% confidence intervals for Rainbow Trout at the Lufkin monitoring reach on the South Fork Snake River from 2014 through 2018.

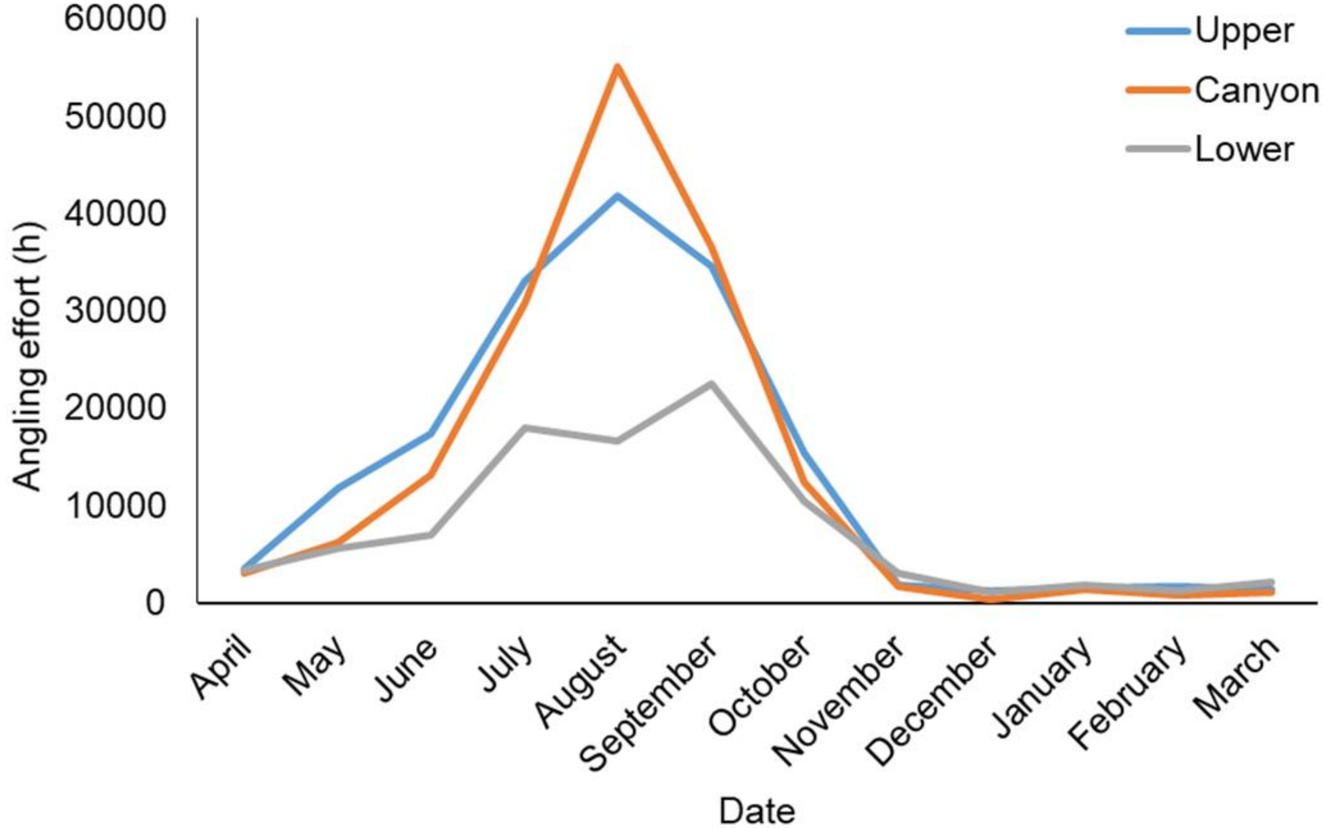

Figure 14. Estimated angler effort for each survey strata (two-week intervals) by river sections in the South Fork Snake River from April 2017 through March 2018.

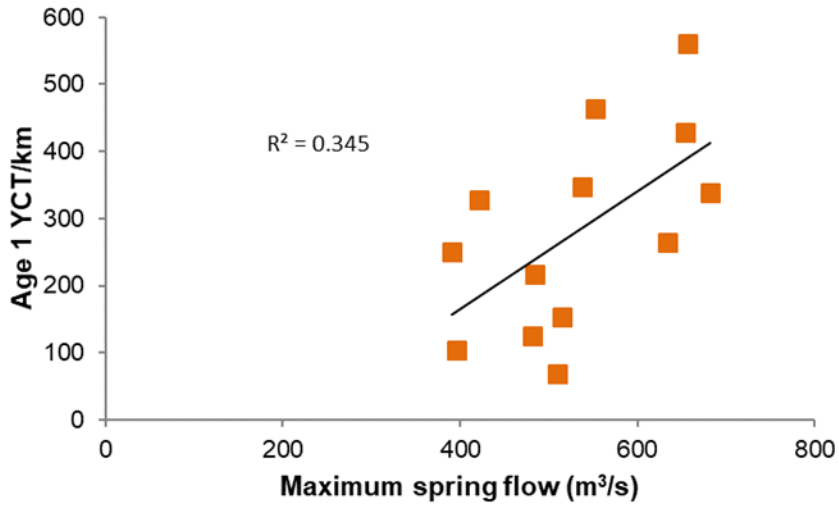

Figure 15. The relationship of age-1 Yellowstone Cutthroat Trout (YCT) abundance with maximum spring flows the previous year.

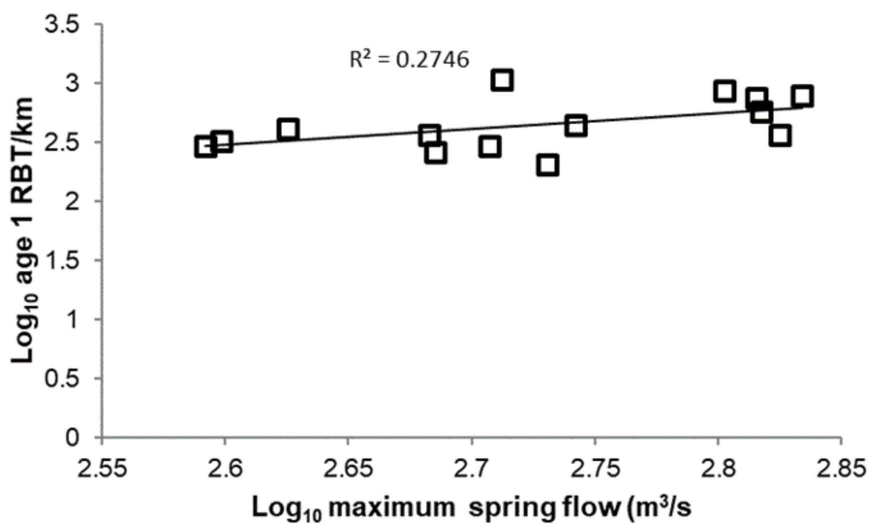

Figure 16 The log-transformed relationship of age-1 Rainbow Trout (RBT) abundance with maximum spring flows the previous year.

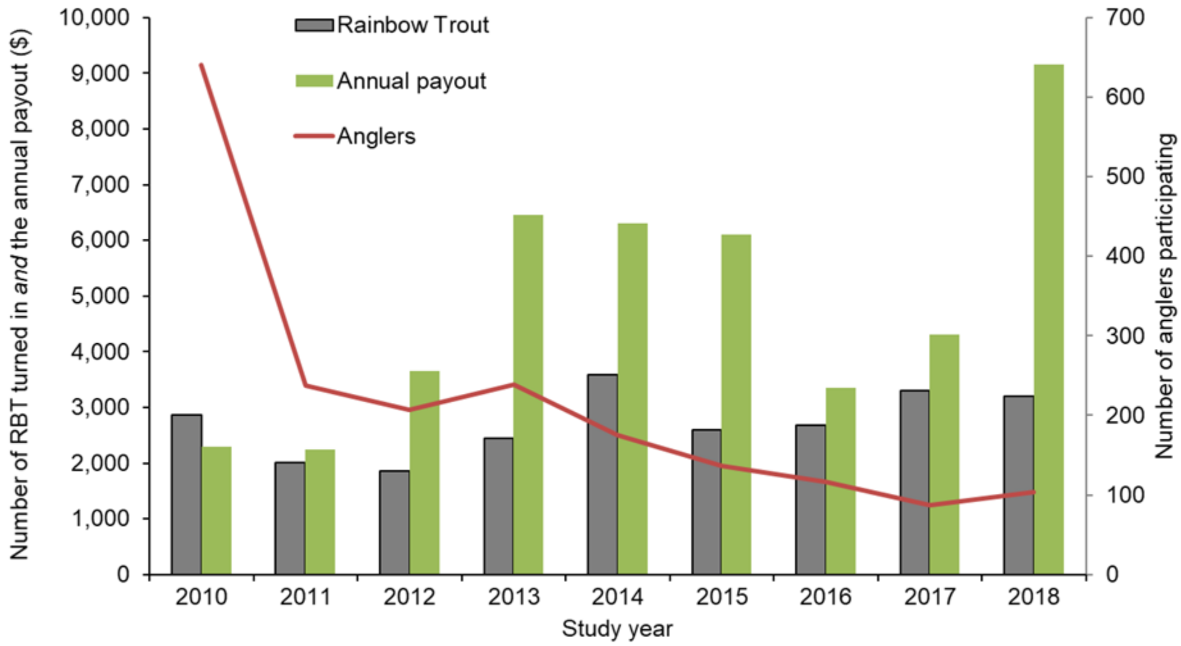

Figure 17. The annual number of anglers participating in the South Fork Snake River Angler Incentive Program and the number or Rainbow Trout (RBT) turned in since the program started in 2010.

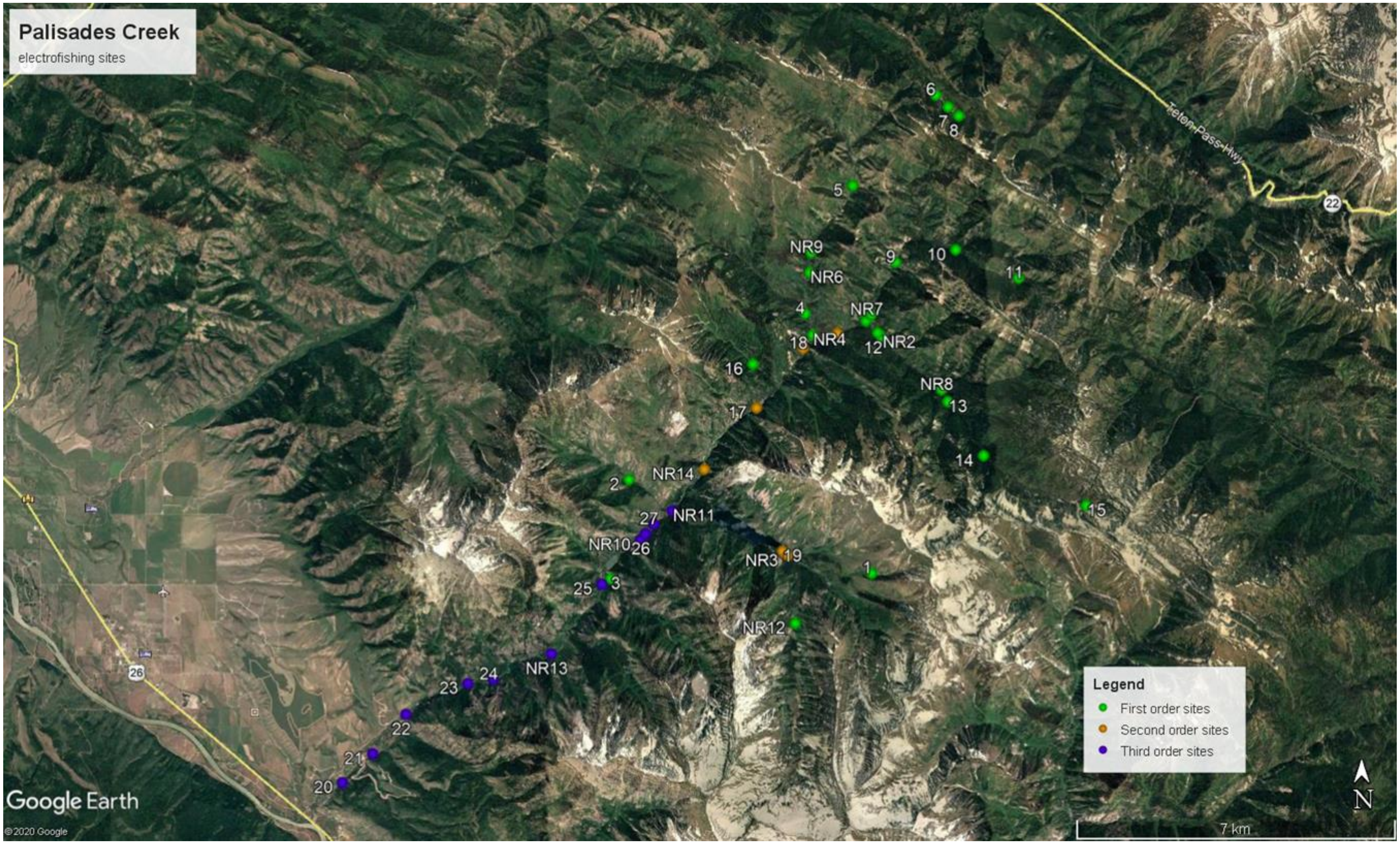

Figure 18. Randomly selected backpack electrofishing sites on Palisades Creek, 2018.

HENRYS FORK SNAKE RIVER

ABSTRACT

We used boat mounted electrofishing equipment to assess fish populations in the Box Canyon, Vernon, and Chester reaches of the Henrys Fork Snake River during 2018. In Box Canyon, Rainbow Trout *Oncorhynchus mykiss* densities were 1,738 fish per km (± 176; 95% CI), which was similar to the 24 year average trout density (1,880 trout per km). The effects of winter flows on Rainbow Trout first-winter survival continue to be significantly related to predicting age-2 abundance from population estimates (Log_{10} age-2 Rainbow Trout abundance = 0.6342 log_{10} mean winter flow + 1.855; r^2=0.45). Age-2 trout abundance predicted by the flow model was 1,851 fish, and we estimated abundance at 2,865 based on the mark-recapture estimate. We observed a strong year class strength of age-2 Rainbow Trout that should contribute substantially to the fishery in 2018-2019. In the Vernon reach, we estimated 995 trout per km (± 1,119) with a species composition of 34% Brown Trout *Salmo trutta* and 66% Rainbow Trout in our spring survey. Trout densities in the Vernon Reach increased drastically when compared to the density of 433 trout per km (± 146) from the previous spring survey conducted in 2015. We estimated 752 trout per km (± 74) in our spring survey in the Chester reach. Species composition was 41% Brown Trout and 59% Rainbow Trout in the Chester reach. Trout densities decreased in the Chester reach in 2018 when compared to the density from previous surveys conducted in 2015 of 615 trout per km (± 104). We continued to observe a slight shift in species composition in the HFSR downstream of Mesa Falls, with Brown Trout increasing in species composition 2.2% and 1.8% per year in the Vernon and Chester reaches, respectively, since the early 2000s. Similar to previous evaluations, we found a significant proportion of the population was composed of larger trout (> 500 mm) in the Vernon reach and to a lesser extent in the Chester reach suggesting that trophy-sized trout are abundant and available to anglers.

Authors:

John Heckel
Regional Fisheries Biologist

Jon Flinders
Regional Fisheries Biologist

Brett High
Regional Fisheries Manager

INTRODUCTION

The Henrys Fork Snake River (Henrys Fork) is a popular fishery that attracts anglers from throughout the nation and across the globe. An economic survey conducted in 2003 showed that Fremont County, which encompasses a large portion of the Henrys Fork drainage, ranked first out of the 44 counties in Idaho in terms of angler spending (Grunder et al. 2008).

The Henrys Fork forms at the confluence of Big Springs Creek and the Henrys Lake Outlet, and flows approximately 25 km before reaching Island Park Dam. Downstream of Island Park Dam, the Henrys Fork flows approximately 147 km and through two smaller dams and four irrigation check dams before joining the South Fork Snake River to form the Snake River. The Henrys Fork fishery upstream of Island Park Reservoir is primarily supported by stocked catchable trout (Flinders et al. 2016). The fishery is also supported by trout that move out of Henrys Lake or Island Park Reservoir. Management of the Henrys Fork downstream of Island Park Dam emphasizes wild populations without hatchery supplementation. The Henrys Fork downstream of Island Park Dam, particularly the Box Canyon, Harriman Ranch, and Pinehaven reaches, support world famous wild Rainbow Trout *Oncorhynchus mykiss* fisheries. Downstream of the Harriman Ranch, the Henrys Fork flows over Mesa Falls and is joined by Warm River before it is impounded by Ashton Dam. Brown Trout *Salmo trutta* are present in the Henrys Fork downstream of Mesa Falls, and increase in numbers in downstream reaches, eventually dominating species composition (>70%) around the town of St. Anthony and downstream.

Previous research has emphasized the importance of winter river flows to the survival of age-0 Rainbow Trout in the Box Canyon reach (Garren et al. 2006a, Mitro 1999). Higher winter flows in this reach result in significantly higher overwinter survival of juvenile trout and subsequent recruitment to the fishery downstream from Island Park Reservoir. Implementation of a congressionally-mandated Drought Management Plan has improved communications among interested parties and planning regarding winter discharges. We will continue to work cooperatively with stakeholders to maximize wild trout survival, based on timing and magnitude of winter releases from Island Park Dam.

STUDY SITE

During 2015, we sampled the Box Canyon, Chester, and Vernon reaches of the Henrys Fork Snake River (Figure 19). The Box Canyon reach is sampled on an annual basis as part of our long-term monitoring program for the Henrys Fork Snake River. The Box Canyon reach started downstream of Island Park Dam at the confluence with Buffalo River and extended downstream 3.7 km to the end of a large pool. The Vernon reach started at the Vernon boat ramp and continued downstream 4.4 km to the Chester backwaters. The Chester reach started immediately downstream of Chester Dam and extended downstream 5.7 km to the backwaters upstream of the Fun Farm Bridge. Coordinates for all mark-recapture transect boundaries are presented in Appendix A.

OBJECTIVE

To obtain current information on fish population characteristics for fishery management decisions on the Henrys Fork Snake River.

METHODS

During 2018, we sampled all survey reaches using three electrofishing rafts. Two rafts electrofished areas near each bank while the third raft electrofished in the middle of the channel. Approximately every half mile all three boats would meet on one side of the river, work up fish, and release fish at the work-up station. Electrofishing would then begin about 50-100 m downstream from the work-up station to reduce recapturing marked fish from the work-up station. In the Box Canyon reach, we marked fish on May 8, and recaptured fish on May 10. Two passes per boat were made on each marking and recapture day for a total of six passes per day for both marking and recaptures. In the Vernon reach, we marked fish on May 25, and recaptured fish on May 30. In the Chester reach, we marked fish on April 26, and recaptured fish on May 1. All trout and Mountain Whitefish *Prosopium williamsoni* captured from mark-recapture surveys were identified to species and measured for total length (TL) to the nearest mm. Because the capture efficiency of trout decreases for smaller fish, those fish ≥150 mm were marked with a hole punch in the caudal fin prior to release.

In all reaches, we estimated densities for all trout and Mountain Whitefish ≥ 150 mm using the log-likelihood method in Fisheries Analysis+ software (FA+; Montana Fish, Wildlife, and Parks 2004). Proportional stock densities (PSD) were calculated as the number of individuals (by species) ≥ 300 mm / by the number ≥ 200 mm. Similarly, relative stock densities (RSD-400) used the same formula, with the numerator replaced by the number of fish ≥ 400 mm (Anderson and Neumann 1996). After population estimates were calculated, we estimated trends in species composition in the Vernon and Chester reaches using linear regression.

We evaluated the relationship of winter flows on juvenile Rainbow Trout winter survival in Box Canyon by using linear regression to examine the relationship between age-2 Rainbow Trout abundance and mean winter (Dec 1–Feb 28) stream flow (cubic feet per second [cfs]) of age-2 Rainbow Trout during their first winter as described by Garren et al. (2006a). We log-transformed age-2 Rainbow Trout abundance and mean winter flow data from the past 20 surveys to establish the following relationship:

$$\log_{10} \text{age-2 Rainbow Trout abundance} = 0.6342 \log_{10} \text{winter stream flow} + 1.855$$

Using this equation we predicted the expected abundance of age-2 Rainbow Trout in our 2018 population estimate based on mean winter stream flows observed during 2016 (i.e., December 2016–February 2017). To validate this relationship, we determined age-2 Rainbow Trout abundance during the 2018 electrofishing surveys by estimating the number of fish between 230 and 329 mm, which correlates to the lengths of age-2 trout in past surveys (Garren 2006a). Age-2 Rainbow Trout were determined to be the first year class fully recruited to the electrofishing gear (Garren 2006b). We then compared predicted and observed age-2 Rainbow Trout abundance in Box Canyon to evaluate the ability of the equation above to predict year class strength based on winter flow. Data from 2018 were added to the flow vs. age-2 abundance regression model and this model will continue to be used in management of winter flow releases from Island Park Dam.

RESULTS

Box Canyon

We collected 1,434 fish during two days of electrofishing in the Box Canyon reach. Species composition was 88% Rainbow Trout, 9% Mountain Whitefish, and 2% Brook Trout *Salvelinus fontinalis*. Rainbow Trout ranged in size from 90 to 560 mm, with a mean and median TL of 256 (± 4.7; 95% CI) and 265 mm, respectively (Figure 20; Appendix B). Rainbow Trout PSD and RSD-400 were 45 and 11, respectively (Table 10). We used the log-likelihood method (LLM) to estimate 6,430 Rainbow Trout ≥ 150 mm (650 ±; 95% CI; Table 11; Appendix C) in the reach, which equates to 1,783 fish/km (Figure 21). Our efficiency rate (ratio of marked fish during the recapture runs [R] to total fish captured on the recapture run [C]), unadjusted for size selectivity was 14% (Appendix C). We estimated 1,045 Mountain Whitefish ≥ 150 mm for the reach, based on the Peterson estimate with a Chapman modification, with 95% confidence intervals of 452 to 2,568 (Figure 22). We estimated 282 Mountain Whitefish/km and the efficiency rate (unadjusted for size selectivity) was 7%.

The regression model relating winter flow (December-February) to age-2 abundance estimated an abundance of 1,851 age-2 Rainbow Trout in the 2018 survey based on winter flows that averaged 170 cfs in the winter of 2016. However, based on the length-based estimates of abundance using the LLM, we estimated age-2 Rainbow Trout abundance at 2,865 fish in the Box Canyon reach during 2018 (Figure 23). Among most years, the regression model accurately estimates the relative year class strength of Rainbow Trout using mean winter stream flow (Linear regression, $r^2 = 0.45$, $F_{1, 19} = 15.79$, $p < 0.001$) and is a useful tool to evaluate the effects of variable winter flows.

Vernon

We collected 1,009 fish during two days of electrofishing in the Vernon reach of the Henrys Fork. Species composition of trout collected was 57% Rainbow Trout, 30% Brown Trout, 12% Mountain Whitefish, < 1% Brook Trout, and < 1% Yellowstone Cutthroat Trout *O. clarkii bouvieri*. Rainbow Trout ranged between 92 and 556 mm (Figure 24), with a mean and median TL of 330 (± 8.6) and 310 mm, respectively. Rainbow Trout PSD and RSD-400 values were 63 and 35, respectively. Brown Trout ranged between 113 and 620 mm with a mean and median TL of 294 (± 14.2) and 294 mm, respectively. Brown Trout PSD and RSD-400 values were 79 and 44, respectively. Length-frequency distribution of Rainbow Trout captured in the Vernon reach of the Henrys Fork Snake River during the spring of 2018 diverged from the average distributions from 2005 to 2007, 2009, 2012, and 2015 with a stronger than normal year class of age-2 fish near 300 mm (Figure 25). Brown Trout in 2018 exhibited two pronounced peaks in the length-frequency distribution at ~150 and ~300 mm when compared to the average distribution from 2005-2007, 2009, 2012, and 2015. We estimated 2,969 Rainbow Trout ≥ 150 mm for the reach (± 413), which equates to 657 Rainbow Trout/km (Figure 26). Our efficiency rate (unadjusted for size selectivity) was 10%. We estimated 1,400 Brown Trout ≥ 150 mm for the reach (± 187), which equates to 338 Brown Trout/km. Our efficiency rate (unadjusted for size selectivity) for Brown Trout was 20%. We estimated 511 Mountain Whitefish ≥ 150 mm for the reach based on the Peterson estimate with a Chapman modification and 95% confidence intervals of 289 to 1,013 (Figure 26). The number of Mountain Whitefish/km was estimated as 116 and the efficiency rate (unadjusted for size selectivity) was 11%. Based on regression analysis of Brown Trout species composition across time, Brown Trout have increased 2.2% percent in composition per year since 2005 (Linear regression, $r^2 = 0.92$, $F_{1, 5} = 56.16$, $p < 0.01$; Figure 27).

Chester

We collected 1,245 fish during two days of electrofishing in the Vernon reach of the Henrys Fork. Species composition was 55% Rainbow Trout, 38% Brown Trout, 7% Mountain Whitefish, and <1% Brook Trout. Rainbow Trout TL ranged between 104 and 522 mm (Figure 28), with a mean and median total length of 359 (± 5.8) and 356 mm, respectively. Rainbow Trout PSD and RSD-400 values were 71 and 37, respectively. Brown Trout ranged between 132 and 591 mm with a mean and median total length of 380 (± 7.7) and 392 mm, respectively. Brown Trout PSD and RSD-400 values were 86 and 47, respectively. Length-frequency distribution of Rainbow Trout and Brown Trout captured in the Chester reach of the Henrys Fork during the spring of 2018 diverged from average distributions from 2003, 2007, 2009, 2012, and 2015, with a pronounced peak at ~300 mm in the length frequency for both species (Figure 29). We estimated 2,960 Rainbow Trout ≥ 150 mm for the reach (± 434), which equates to 447 Rainbow Trout/km. Our efficiency rate (unadjusted for size selectivity) was 10%. We estimated 1,400 Brown Trout ≥ 150 mm for the reach (± 187), which equates to 306 Brown Trout/km. Our efficiency rate (unadjusted for size selectivity) for Brown Trout was 19%. We estimated 676 Mountain Whitefish ≥ 150 mm for the reach, based on the Peterson estimate with a Chapman modification and 95% confidence intervals of 256 to 1,631 (Figure 22). The number of Mountain Whitefish/km was estimated as 119 and the efficiency rate (unadjusted for size selectivity) was 4%. Based on regression analysis of Brown Trout species composition over time, Brown Trout have increased 1.8% in percent composition per year since 2003 (Linear regression, r^2=0.84, F(1,4)=20.83, p=0.01; Figure 27).

DISCUSSION

Trout density in Box Canyon in 2018 (1,783 fish/km) was similar to 2017 and only slightly below (5.5%) the 22-year average of 1,886 trout/km. The Rainbow Trout length-frequency distribution in 2018 indicates strong year classes of age-1 and age-2 trout. This suggests that overwinter flow management, potentially aided with a couple good water years has contributed to better overwinter survival of juvenile Rainbow Trout. Therefore, we anticipate anglers having the opportunity for high catch rates in the Box Canyon reach over the next several years.

Winter stream flows continue to be an important factor in determining Rainbow Trout abundance in the Box Canyon reach (Garren et al. 2006a). However, observed age-2 abundance (2,865) in 2018 was outside of the 95% CIs predicted from the regression model (1,851), suggesting that additional factors aside from winter flows contribute to age-2 Rainbow Trout abundance. Flows during the winter of 2016-2017 would have affected age-2 fish in the 2018 survey. Fausch et al. (2001) found Rainbow Trout recruitment was higher in tailwaters exhibiting high winter and/or low spring flows. High spring flows can reduce year class strength due to substrate scouring displacing eggs and fish larvae, or from redd desiccation when flows are too low. Higher or lower spring flows may play a role in reducing/increasing year class strength in the Henrys Fork and subsequently cause slight divergences in predictions of the winter flow model. In the past five years (2013-2017), average spring (March-May) flows ranged from 398-648 cfs (mean = 491; SD = 96). Spring flows have been consistent during that time, which may impact recruitment rates. Past studies in the Henrys Fork have found winter flows are the primary determinant regulating the survival of YOY due to the reduction of complex habitat along the river margins when flows are too low (Meyer and Griffith 1997; Mitro et al. 2003). Incorporating spring flows into the winter flow model may make regression model predications more robust, if spring flows indeed regulate recruitment to a varying degree in the Rainbow Trout population in Box Canyon.

Trout densities in the Chester reach have increased approximately 61% since 2009, when we began sampling this reach on a triennial basis. In the last several years, the Crosscut and Last Chance Canals below Chester Dam have been operated throughout the irrigation season. Fish screening may have contributed to the observed increase in trout abundance in the Chester section by reducing fish entrainment and allowing those fish to persist in the fishery. In an unscreened diversion, fish will enter the irrigation system and likely incur mortality. If the diversion is screened, fish are bypassed and returned to the main channel. In 2014, IDFG conducted an evaluation of the bypass tubes at the canals to determine whether fish were bypassed effectively and with minimal mortality. We found the bypass tubes and fish screens were functioning properly with minimal fish mortality. Waters et al. (2012) evaluated fish screens in the Lemhi River, Idaho, and found that under median-streamflow conditions with unscreened diversions the estimated cumulative effect of diversions (41-71 water diversions) was a loss of 71.1% of out-migrating Chinook salmon *O. tshawytscha* smolts due to entrainment. A single diversion can have considerable effects on the population. For example, a diversion in the Yellowstone River was found to have caused more than half of all non-fishing mortality in Sauger *Sander Canadensis* (Jaeger et al. 2005). Currently, we do not have data on the encounter rates of salmonids on the Crosscut and Last Chance canals, but the locations of the diversions may be such that there are high fish encounter rates. Quantifying entrainment and setting screening priorities should be considered in other regional waters, if appropriate funding is available.

Similar to past evaluations, we found a substantial proportion of the population consisted of larger trout (> 500 mm) in the Vernon reach and to a lesser extent in the Chester reach (Garren et al. 2006). Average trout size tends to be much higher in Vernon and Chester reaches, in comparison to other reaches (e.g., Box Canyon) in the Henrys Fork. Previous surveys have documented similar population characteristics of high densities of larger trout and apparent year-class recruitment failures (Garren et al. 2006). However, the high frequency of Brown Trout between 100-200 mm is evidence that juvenile recruitment in the Vernon reach. Adult abundance has remained relatively stable since the early 2000s. Recruitment of juvenile fish into the system is likely coming from tributaries (e.g. Fall River) and/or the main-stem of the Henrys Fork, but due to the width of the Henrys Fork in this reach our sampling techniques are not effective at sampling juvenile trout. We continue using three boats and run multiple passes, but additional sampling that focuses on stream margins and other juvenile habitat is warranted. Future research should focus on identifying key sources of juvenile production. Identifying juvenile rearing habitats will allow managers to develop appropriate protective measures to ensure these unique fisheries continue to produce trophy angling opportunities.

We continued to observe a shift in species composition in the Henrys Fork downstream of Mesa Falls from a predominately Rainbow Trout to Brown Trout population (High et al. 2011). In the Vernon reach, Brown Trout increased from 4% of the species composition in 2005 to 30% in 2018. Similarly, in the Chester reach, Brown Trout increased from 9% of the species composition in 2003 to 38% in 2018. The shift towards a Brown Trout dominated system may be due to both abiotic (e.g. temperature; flow) and biotic factors (e.g. competition). For example, stable flows have been found to increase spawning activity in Brown Trout populations (Pender and Kwak 2002), which is an advantage Brown Trout may have over Rainbow Trout in the Henrys Fork. During Rainbow Trout spawning periods in the spring, there are generally more fluctuations in flow regimes as low-elevation snow begins to melt, large rain events can occur, and reservoir storage and discharge are manipulated to prepare for irrigation season, but during the fall spawning season for Brown Trout flows are generally very similar from year-to-year and there is no irrigation demand during that time. Whereas, fluctuations and increases in discharge can increase mortality rates of Rainbow Trout eggs (Korman et al. 2017) and can control recruitment (Dibble et al. 2015). Additionally, there has not been a change in fishing regulations since 2005, whereas this section was under a quality trout regulation prior to 2004. Therefore, abiotic factors, e.g., discharge are likely contributing to the shift in species composition we are observing.

In addition to a shifting trout species composition, we estimated a declining Mountain Whitefish population. In the Box Canyon reach, confidence intervals overlap from 2002 to 2018 suggesting that there is not a significant difference in abundance over that time period. However, in the Vernon and Chester reaches Mountain Whitefish estimates are at an all-time low since 2002. Vernon and Chester do not have as much pool habitat as the upper river in Box Canyon, which is the preferable habitat for Mountain Whitefish. Furthermore, habitat alterations such as impoundments and changes in flow regimes have been shown to negatively impact Mountain Whitefish populations (Meyer et al. 2009). Flow regimes are a major challenge in managing fish populations in the Henrys Fork River as it is used heavily for irrigation, and reservoir storage to support flows for maintaining water rights can vary widely from year to year since storage is predominately supported by snowmelt. Therefore, flow regimes that are heavily influenced by snowmelt and used for irrigation are unpredictable and ultimately can have a negative effect on salmonid populations that rely on stable flows. We need to continue monitoring Mountain Whitefish in all reaches of the Henrys Fork and make estimating their abundance a priority during population estimates, or separate surveys should be conducted to focus on this native species.

RECOMMENDATIONS

1. Continue annual population surveys in the Box Canyon to quantify population response to changes in the flow regime over time. Collect Rainbow Trout otoliths for age, growth, and morality analyses.

2. Continue to collaborate with the irrigation community and other agencies to obtain increased winter flows out of Island Park Dam to benefit trout recruitment, stressing the importance of early winter flows (December, January and February) to age-0 trout survival.

3. Investigate the role of spring flows to improve the accuracy of the winter flow model.

4. Develop and implement creel surveys in the Henrys Fork to monitor angler use and harvest in areas where harvest is allowed.

5. Identify juvenile trout rearing areas in the lower Henrys Fork.

Table 10. Trout population index summaries (±95% confidence intervals) for the Henrys Fork Snake River, Idaho 2018. Total length (TL), proportional stock density (PSD), and relative stock density (RSD) are presented in the table.

River Reach	Species	Mean TL (mm)	Median TL (mm)	PSD	RSD-400	RSD-500	Density (No./km)	Species Composition (%)
Box Canyon	Rainbow Trout	256 (±4.7)	265	45	11	0	1,738 (±176)	100
Vernon	Rainbow Trout	330 (±8.6)	310	63	35	6	657 (±79)	66
	Brown Trout	294 (±14.2)	294	79	44	15	338 (±40)	34
Chester	Rainbow Trout	359 (±5.8)	356	71	37	1	447 (±44)	59
	Brown Trout	380 (±7.7)	392	86	47	7	306 (±30)	41

Table 11. Log-Likelihood Method (LLM) population estimates of trout (≥150 mm) and Mountain Whitefish from the Henrys Fork Snake River, Idaho during 2018.

River reach	Species	No. marked	No. captured	No. recaptured	Population Estimate	Confidence Interval (±95%)	Density (No./km)	Discharge[1] (ft^3/s)
Box Canyon[2]	Rainbow Trout	715	646	93	6,430	650	1,738	1,067
	Mountain Whitefish[4]	88	46	3	1,045		282	
Vernon[3]	Rainbow Trout	235	384	40	2,969	413	657	2,260
	Brown Trout	164	167	33	1,400	187	338	
	Brook Trout[4]	2	5	2	5	--	1	
	Yellowstone Cutthroat Trout	0	1	0	--	--	--	
	Mountain Whitefish[4]	63	71	8	512	--	116	
Chester[3]	Rainbow Trout	281	46	45	2,960	434	447	2,322
	Brown Trout	250	264	50	1,400	187	306	
	Brook Trout	0	2	0	--	--	--	
	Mountain Whitefish[4]	34	57	2	676	--	119	

[1] Represents the mean discharge value between marking and recapture events

[2] Data obtained from USGS gauge (13042500) near Island Park Dam.

[3] Data obtained from USGS gauge (13046000) below Ashton Dam.

[4] Unable to estimate population with LLM therefore used Peterson estimate with Bailey modification

Figure 19. Map of the Henrys Fork Snake River watershed and electrofishing sample sites (Box Canyon, Chester, and Vernon) during 2018.

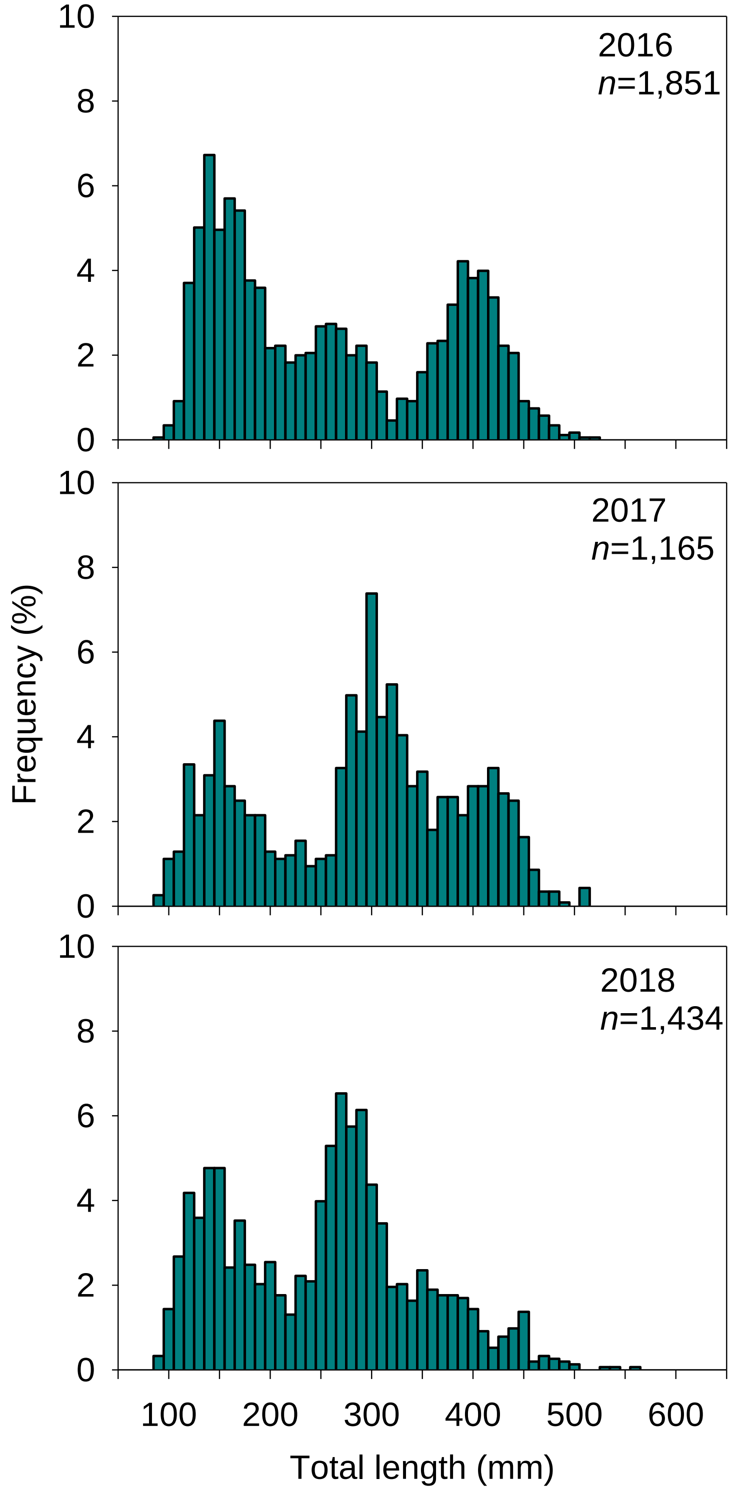

Figure 20. Length-frequency distribution of Rainbow Trout collected by electrofishing in the Box Canyon reach of the Henrys Fork Snake River, Idaho, 2016–2018.

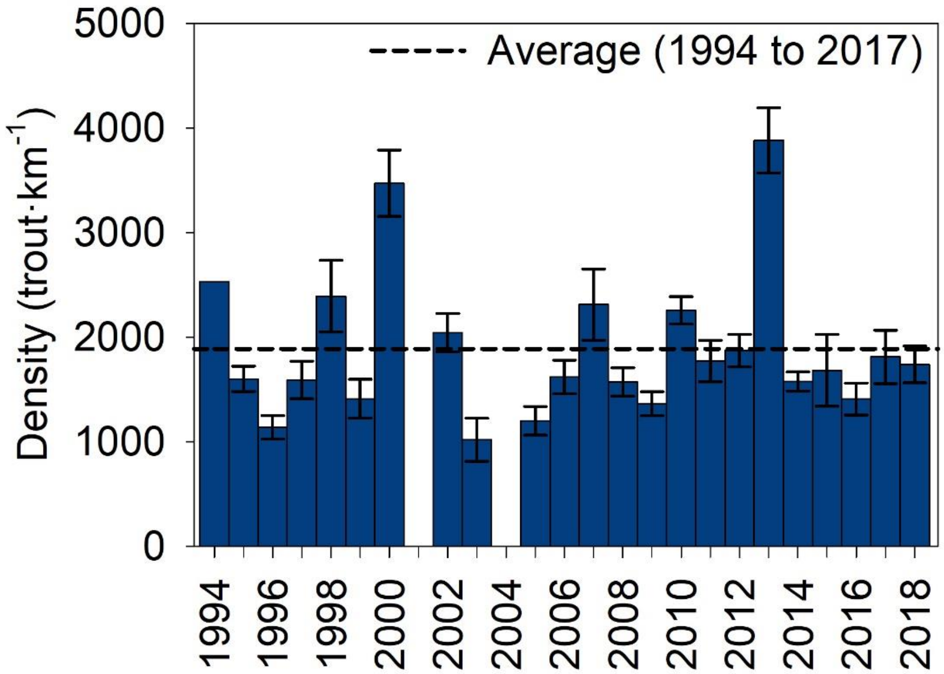

Figure 21. Rainbow Trout density estimates (fish/km) for the Box Canyon reach of the Henrys Fork Snake River, Idaho 1994 - 2018. Error bars represent 95% confidence intervals. The dashed lines represent the long-term average Rainbow Trout density, excluding the current year's survey.

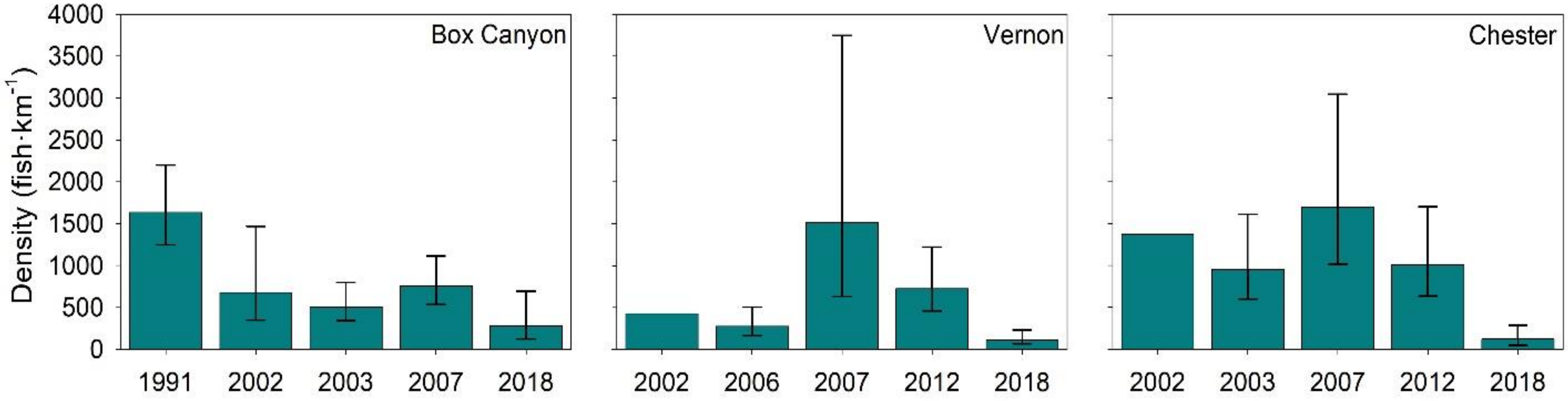

Figure 22. Mountain Whitefish density estimates (fish/km) by year for Box Canyon, Vernon, and Chester reach of the Henrys Fork Snake River, Idaho. Error bars represent 95% confidence intervals. Densities in 2002 for Vernon and Chester reaches only represent an estimate (fish/km) with no associated confidence intervals.

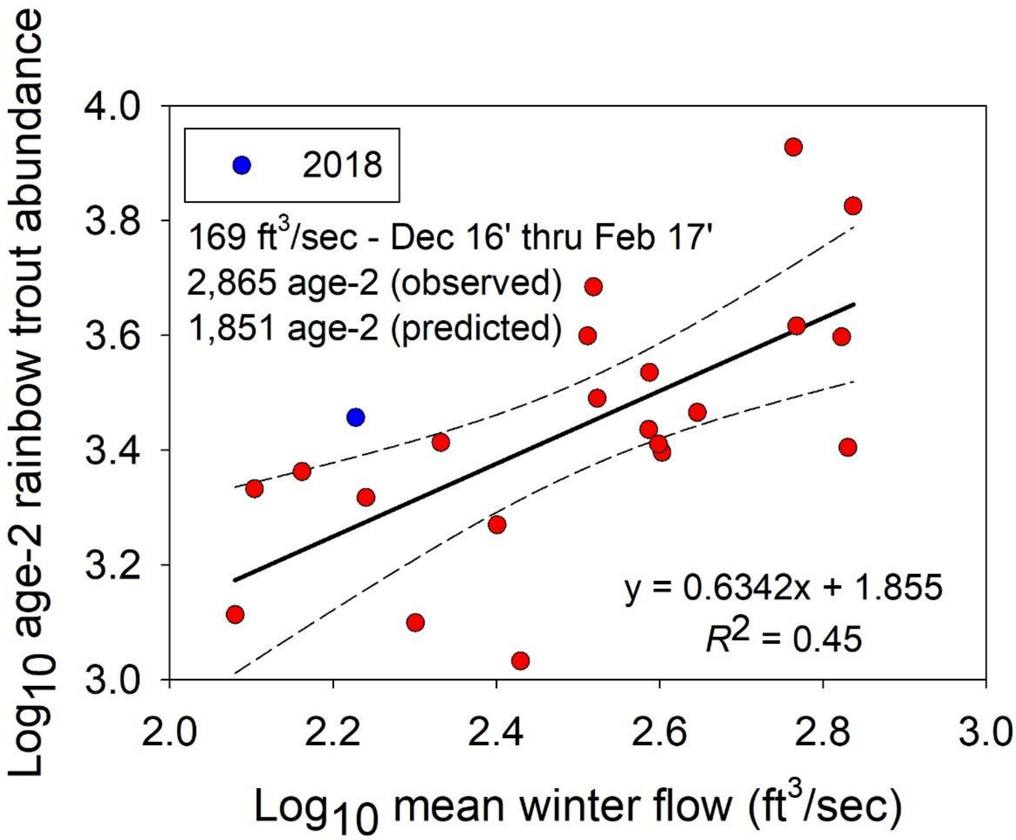

Figure 23. The relationship between age-2 Rainbow Trout abundance and mean winter flow (cfs) during the first winter of a fish's life from 1995-2017; $\log_{10}$ age-2 trout abundance = 0.6342 $\log_{10}$ flow (cfs) + 1.855, (r^2=0.45, $F_{1, 19}$ =15.79, p<0.001). Linear regression and 95% confidence intervals are represented with a solid and dotted line, respectively.

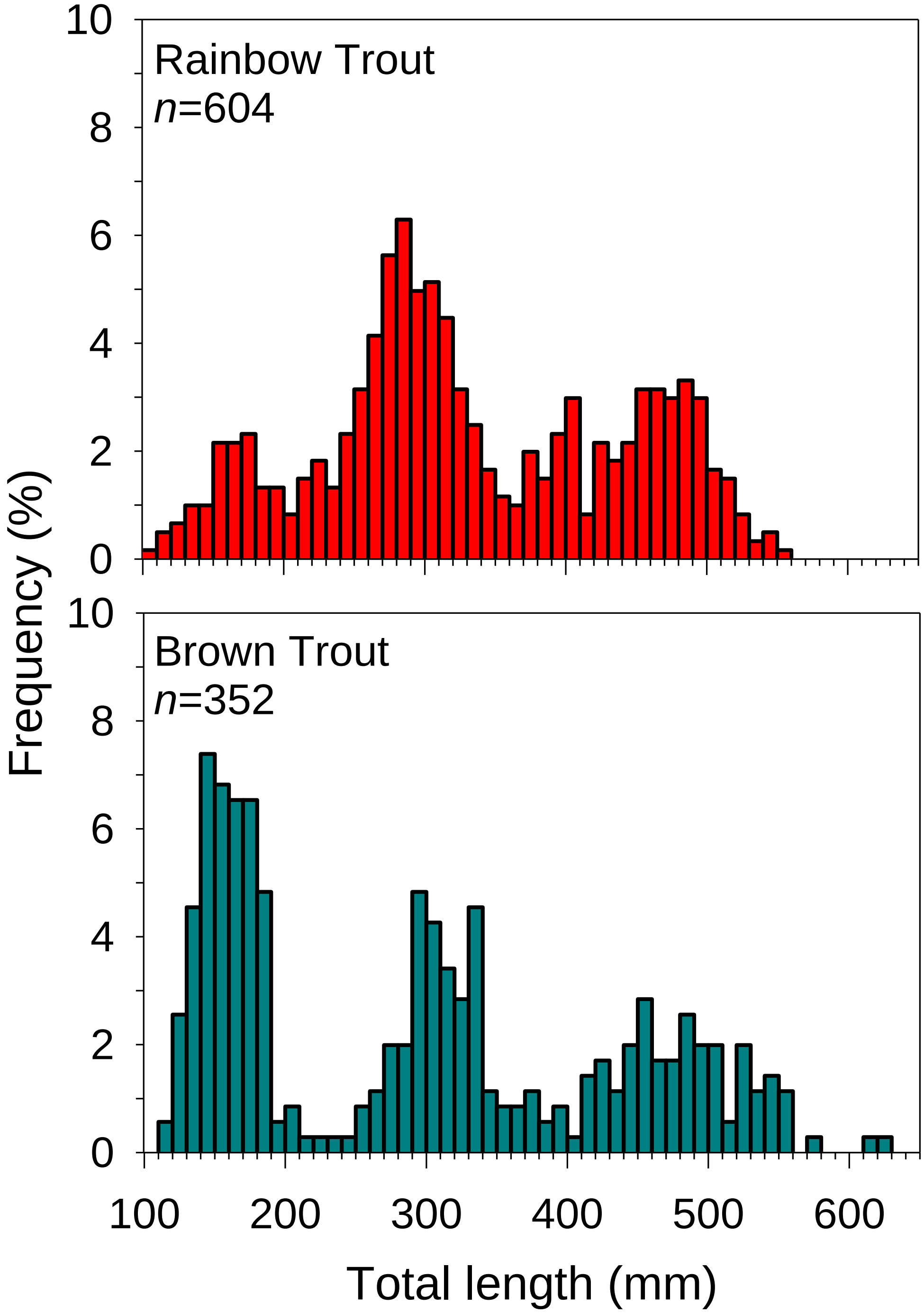

Figure 24. Length-frequency distribution of Rainbow Trout and Brown Trout captured by electrofishing in the Vernon reach of the Henrys Fork Snake River during the spring of 2018.

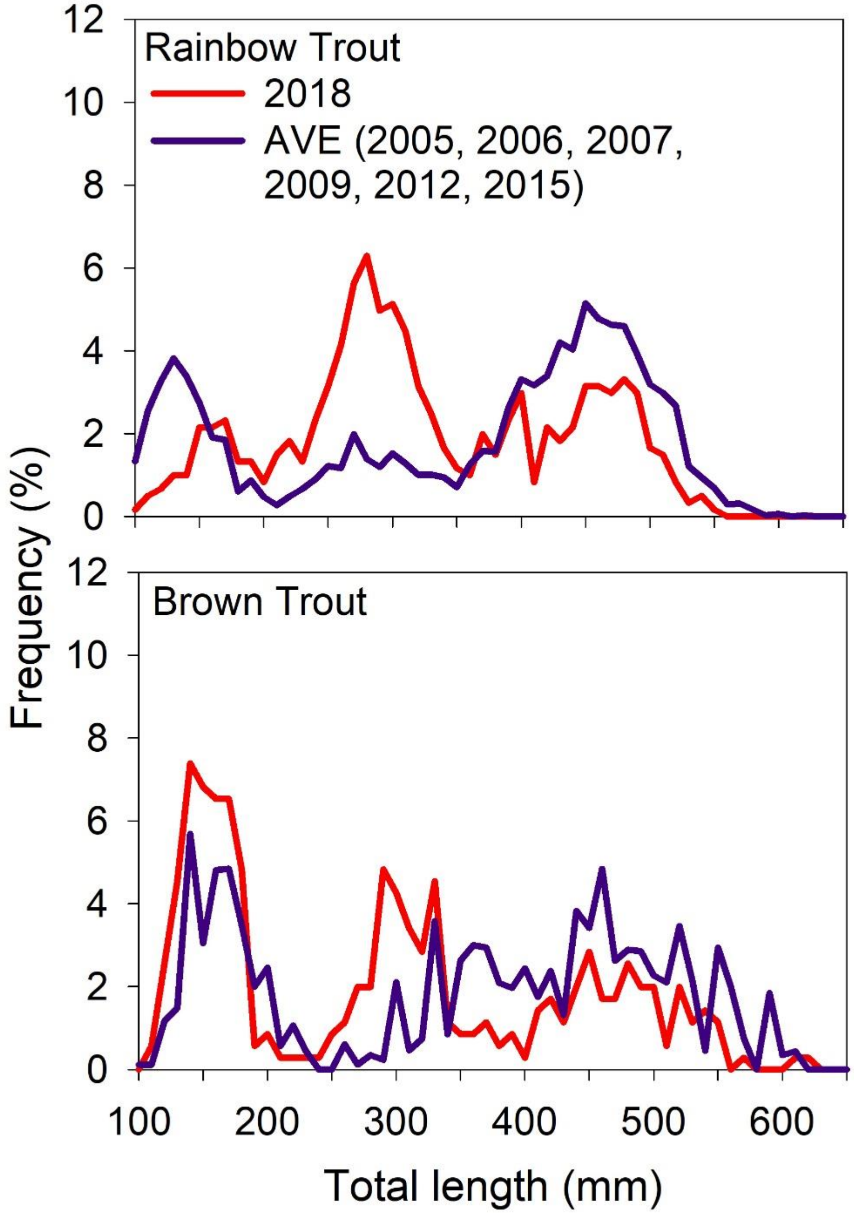

Figure 25. Length-frequency distribution of Rainbow Trout and Brown Trout captured electrofishing in the Vernon reach of the Henrys Fork Snake River during the spring of 2018 compared to the average distribution from 2005 to 2015.

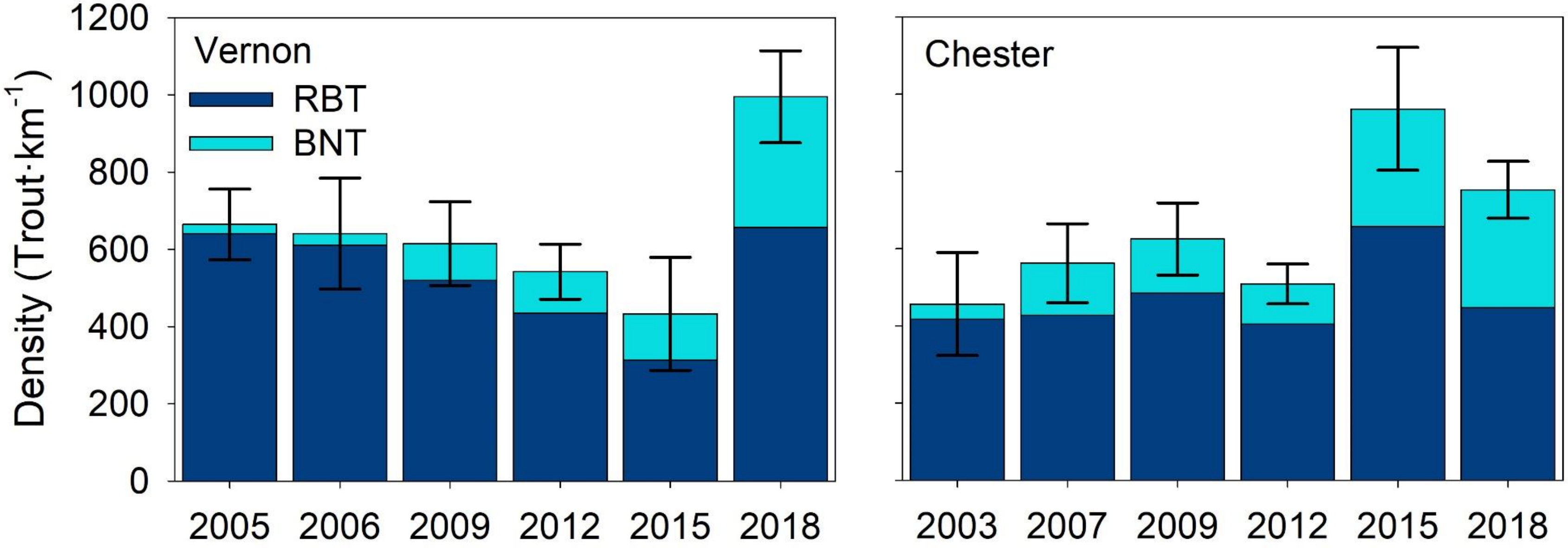

Figure 26. Rainbow Trout (RBT) and Brown Trout (BNT) density estimates (fish per km) from spring electrofishing surveys in the Vernon and Chester reach of the Henrys Fork Snake River, Idaho by year (2003-2018). Error bars represent 95% confidence intervals.

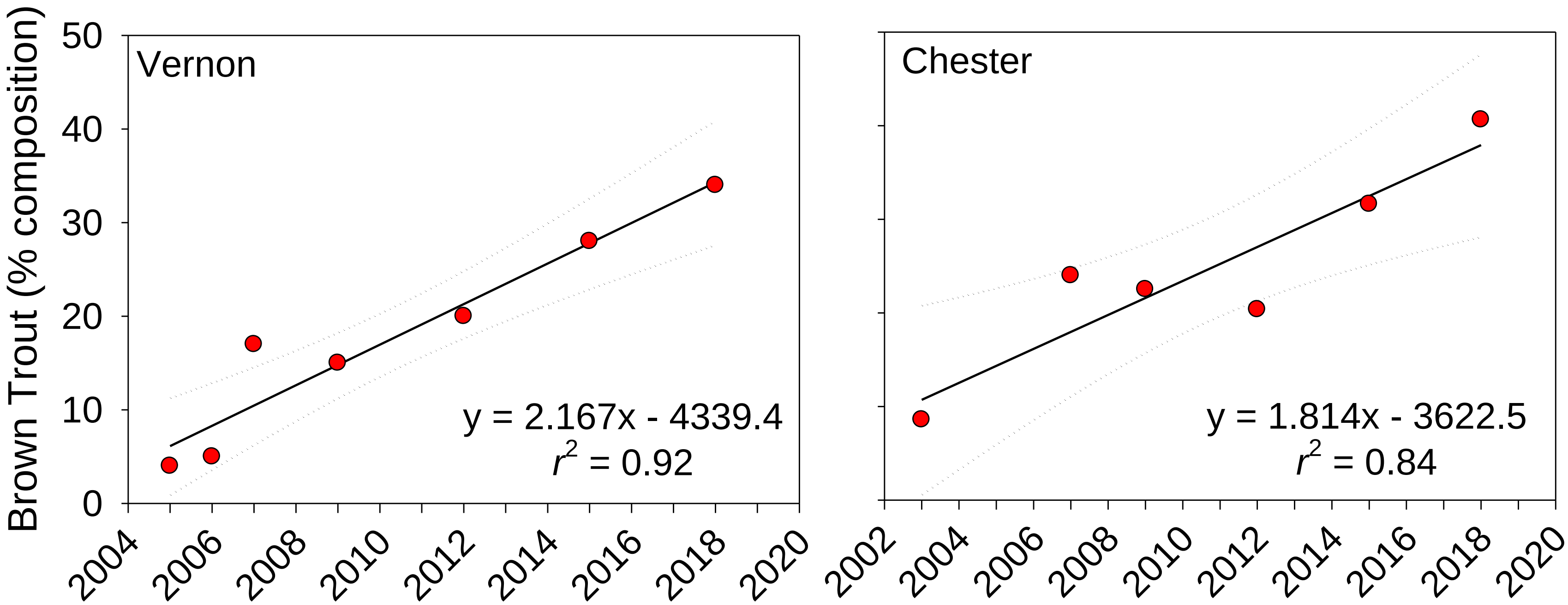

Figure 27. Species composition (%) of Brown Trout in the Vernon and Chester reach of the Henrys Fork Snake River, Idaho collected from electrofishing surveys from 2003 to 2018. Linear regression and 95% confidence intervals are represented with a solid and dotted line, respectively.

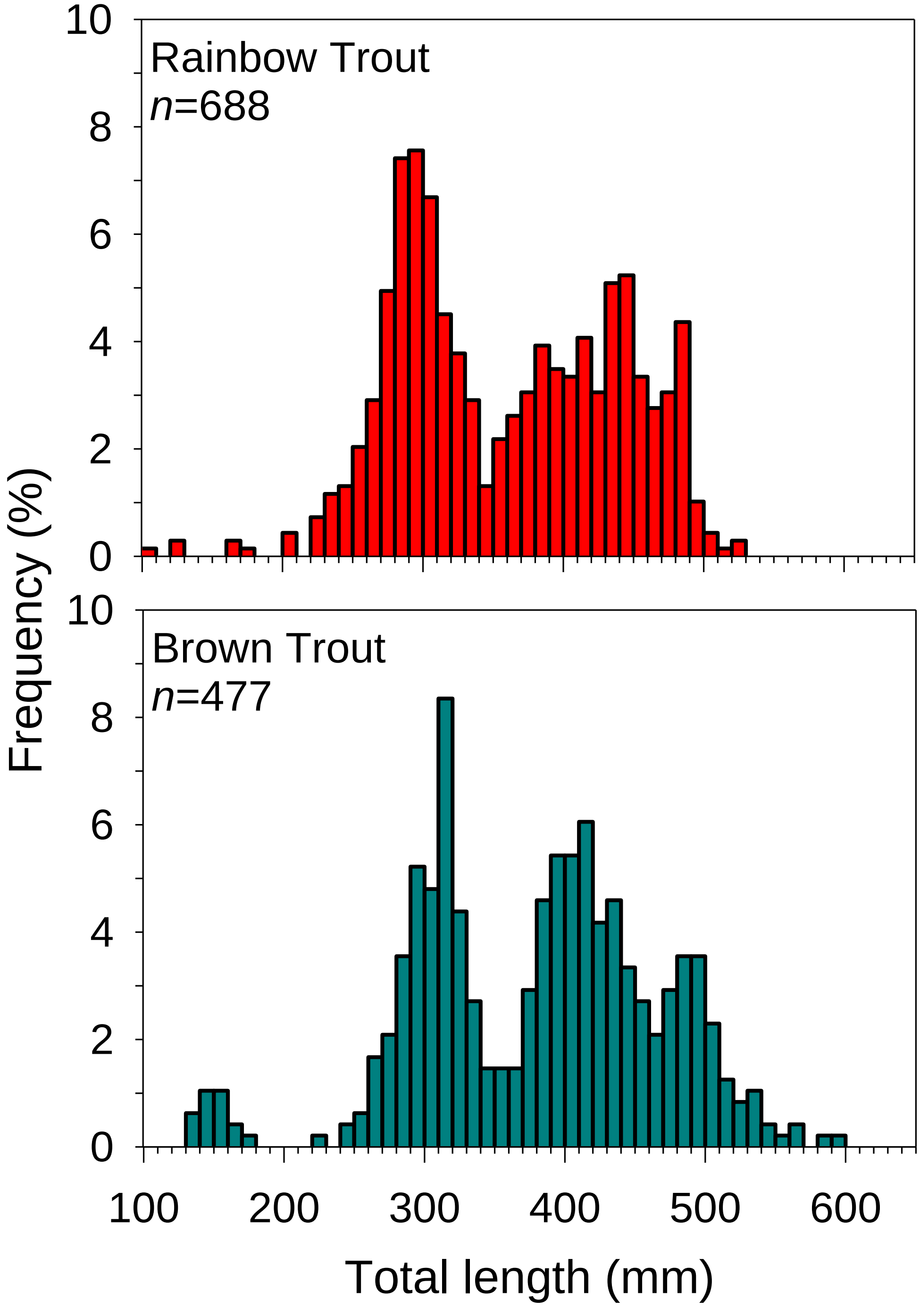

Figure 28. Length-frequency distribution of Rainbow Trout and Brown Trout captured by electrofishing in the Chester reach of the Henrys Fork Snake River during the spring of 2018.

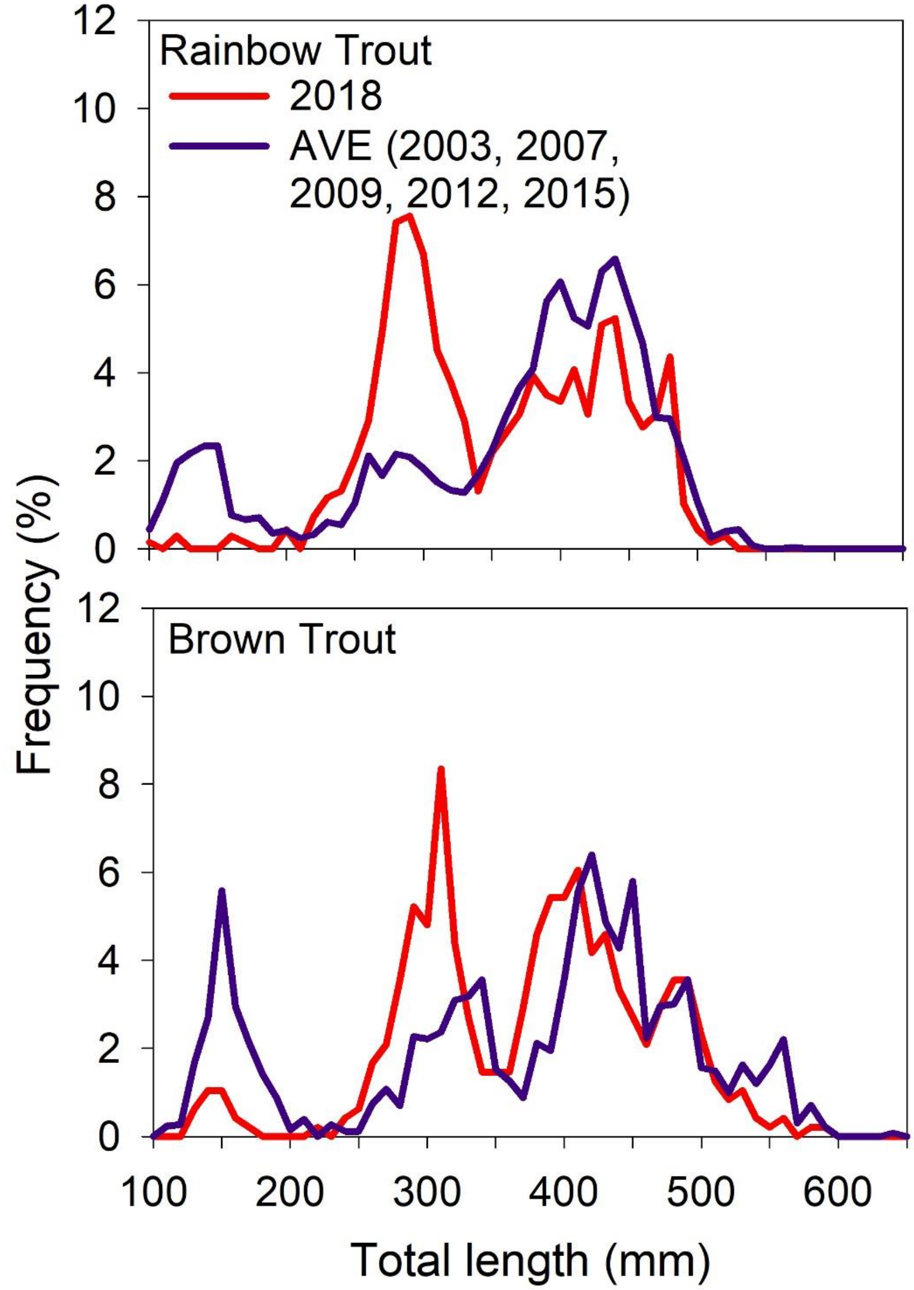

Figure 29. Length-frequency distribution of Rainbow Trout and Brown Trout captured using electrofishing in the Chester reach of the Henrys Fork Snake River during the spring of 2018 compared to the average distribution from 2003 to 2015.

Appendix A. Locations used in population surveys on the Henrys Fork Snake River, Idaho 2018. All locations used NAD27 and are in Zone 12.

	Start		Stop	
Reach	Easting	Northing	Easting	Northing
Box Canyon	468677	4917703	467701	4914352
Vernon	457092	4878151	454184	4875043
Chester	453182	4873986	451042	4871020

Appendix B. Mean total length, length range, proportional stock density (PSD), and relative stock density (RSD-400 and RSD-500) of Rainbow Trout captured in the Box Canyon electrofishing reach, Henrys Fork Snake River, Idaho, 1991-2018. RSD-400 = (number ≥400 mm/ number ≥200 mm) x 100. RSD-500 = (number ≥500 mm/ number ≥200 mm) x 100.

Year	Number	Mean TL (mm)	Length Range (mm)	PSD	RSD-400	RSD-500
1991	711	293	71 – 675	65	46	9
1994	1,226	313	46 - 555	90	46	3
1995	1,590	316	35 – 630	61	30	1
1996	1,049	300	31 – 574	66	20	1
1997	1,272	307	72 – 630	47	14	1
1998	1,187	269	92 – 532	45	13	0
1999	874	330	80 – 573	63	16	1
2000	1,887	293	150 – 593	45	11	1
2002	1,111	352	100 – 600	75	28	0
2003	599	365	100 – 520	86	42	1
2005	1,064	347	93 – 595	76	44	2
2006	1,200	320	95 – 648	64	26	2
2007	1,092	307	91 – 555	58	21	2
2008	1,417	341	92 – 536	73	20	1
2009	1,371	350	80 – 587	79	27	1
2010	2,700	307	75 - 527	51	23	1
2011	1,224	348	111 - 550	74	27	1
2012	1,583	302	77 – 560	57	22	1
2013	2,072	295	110 - 535	39	14	1
2014	1,916	341	106 - 635	80	17	1
2015	1,219	296	90 - 509	83	25	0
2016	1,755	267	99 - 520	62	31	0
2017	1,165	292	84 - 512	72	24	1
2018	1,532	256	90 - 560	45	11	0

Appendix C. Electrofishing mark-recapture statistics, efficiency (R/C), coefficient of variation (CV), Modified Peterson Method (MPM) and Log-Likelihood Method (LLM) population estimates (N) of age-1 and older Rainbow Trout ($\geq$150 mm), and mean stream discharge (ft^3/s) during the sample period for the Box Canyon reach, Henrys Fork Snake River, Idaho, 1995-2018. Confidence intervals ($\pm$95%) for population estimates are in parentheses.

Year	M[a]	C[a]	R[a]	R/C (%)	CV	N/reach MPM	N/reach LLM	N/km LLM	Discharge (ft^3/s)
1995	982	644	104	16	0.04	6,037 (5,043-7,031)	5,922 (5,473-6,371)	1,601 (1,479-1,722)	2,330
1996	626	384	69	18	0.05	3,456 (2,770-4,142)	4,206 (3,789-4,623)	1,137 (1,024-1,250)	1,930
1997	859	424	68	16	0.06	5,296 (4,202-6,390)	5,881 (5,217-6,545)	1,589 (1,410-1,769)	1,810
1998	683	425	42	10	0.07	6,775 (4,937-8,613)	8,846 (7,580-10,112)	2,391 (2,049-2,733)	1,880
1999	595	315	38	12	0.07	4,844 (3,484-6,204)	5,215 (4,529-5,901)	1,409 (1,224-1,595)	1,920
2000	1,269	692	74	11	0.05	11,734 (9,317-14,151)	12,841 (11,665-14,017)	3,471 (3,153-3,788)	915
2002	1,050	511	81	16	0.05	6,574 (5,329-7,819)	7,556 (6,882-8,230)	2,042 (1,860-2,224	820
2003	427	167	20	12	0.10	3,472 (2,147-4,797)	3,767 (3,005-4,529)	1,018 (812-1,224)	339
2005	735	401	90	22	0.06	3,250 (2,703-3,797)	4,430 (3,922-4,938)	1,197 (1,060-1,334)	507
2006	887	356	61	17	0.05	5,112 (4,005-6,219)	5,986 (5,387-6,585)	1,618 (1,456-1,779)	1,783
2007	737	332	51	15	0.08	4,725 (3,598-5,852)	8,549 (7,288-9,810)	2,311 (1,970-2,652)	542
2008	887	615	93	15	0.04	5,818 (4,842–7,089)	5,812 (5,312-6,312)	1,571 (1,436–1,706)	894
2009	673	775	112	14	0.04	4,628 (3,910-5,540)	5,034 (4,610-5,458)	1,361 (1,246-1,476)	1,377
2010	1,309	1,292	262	20	0.03	6,439 (5,820-7,058)	8,341 (7,857-8,825)	2,254 (2,123-2,385)	626

Appendix C (continued)

Year	M[a]	C[a]	R[a]	R/C (%)	CV	N/reach MPM	N/reach LLM	N/km LLM	Discharge (ft^3/s)
2011	639	652	74	11	0.06	5,571 (4,516-6,988)	6,548 (5,816-7,280)	1,770 (1,572-1,968)	1,159
2012	793	901	116	13	0.04	6,120 (5,178-7,313)	6,915 (6,339-7,491)	1,869 (1,713-2,025)	911
2013	1,115	1,301	120	9	0.04	12,008 (10,148-14,349)	14,358 (13,207-15,509)	3,881 (3,570-4,129)	648
2014	1,532	636	175	28	0.06	5,547 (4,901-6,335)	5,828 (5,491-6,165)	1,575 (1,484-1,666)	971
2015	765	351	67	19	0.11	3,964 (3,216-4,989)	6,220 (4,950-7,490)	1,681 (1,338-2,024)	709
2016	1,107	397	107	27	0.06	4,082 (3,486-4,850)	5,208 (4,645-5,771)	1,408 (1,255-1,560)	464
2017	625	425	56	13	0.07	4,679 (3,689-6,065)	6,699 (5755-7,643)	1,811 (1,556-2,066)	918
2018	715	646	93	14	0.05	4,927 (4,097-6008)	6,430 (5,780-7,080)	1,738 (1,562-1,913)	1,067

[a]M = number of fish marked on marking run; C = total number of fish captured on recapture run; R = number of recaptured fish on recapture run.

BIG LOST RIVER

ABSTRACT

We conducted electrofishing surveys in 28 reaches in the Big Lost River basin in 2017 and 2018 to estimate population densities, compare changes in densities to past surveys, evaluate species composition, and to obtain relative abundance data for Mountain Whitefish *Prosopium williamsoni* and other trout species. Trout and Mountain Whitefish abundances in the Upper Big Lost River have decreased when compared to estimates from the 1980s. To examine overwinter survival of juvenile fish (age-0) we stocked adipose-clipped Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* (~60,000 fingerlings) in the fall (October) at three locations in 2016. We were unsuccessful in collecting any adipose-clipped fish from stream surveys in 2017 from sites near release locations, suggesting overwintering habitat may potentially be limiting recruitment. Yellowstone Cutthroat Trout, which were first stocked in 2000, appear to have developed some naturally-reproducing populations, based on the juvenile cutthroat and hybrid trout observed in the surveys.

Authors:

John Heckel
Regional Fisheries Biologist

Jon Flinders
Regional Fisheries Biologist

Brett High
Regional Fisheries Manager

INTRODUCTION

The Big Lost River watershed is located in central Idaho, originating in the Copper Basin and eventually flowing southward to the sinks on the Idaho National Engineering Laboratory site (Figure 30). Climatic conditions in the watershed are relatively dry, with an average annual precipitation of 25 cm. Approximately 40% of the precipitation occurs as snow. Because of the high scenic quality of the area, its numerous recreational opportunities, and its proximity to the resort area of Sun Valley, the Big Lost watershed receives a considerable amount of recreational use. Fishing is one of the most popular recreational activities in the area (Corsi 1989).

Numerous gamefish species are present in the watershed, including; Rainbow Trout *Oncorhynchus mykiss* (RBT), Yellowstone Cutthroat Trout *O. clarkii bouvieri* (YCT), Brook Trout *Salvelinus fontinalis* (BKT), Golden Trout *O. mykiss aquabonita*, Tiger Trout *S. trutta* × *S. fontinalis*, Arctic Grayling *Thymallus arcticus*, kokanee *O. nerka*, and Mountain Whitefish *Prosopium williamsoni*. Sculpin, including Paiute *Cottus beldingi* and Shorthead Sculpin *C. confuses* also occupy various waterbodies in the watershed. Mountain Whitefish (MWF) are believed to be the only salmonid native to the watershed and are recognized as genetically divergent from other MWF populations in the Pacific Northwest (Whiteley et al. 2006). Populations of MWF have declined in abundance compared to the 1980s (IDFG 2007). Factors such as habitat alteration (e.g., channelization and impacts from grazing), irrigation (e.g., entrainment, barriers, dewatering, and changes in flow regime), non-native fish interactions (e.g., competition and predation), disease, and exploitation are identified as possible contributors to the decline. To address the decline in abundance and to expedite recovery efforts, the Idaho Department of Fish and Game (IDFG) developed the MWF Conservation and Management Plan for the Big Lost River Drainage, Idaho (IDFG 2007). The intent of this document is to guide management actions to ensure the MWF population in the Big Lost River drainage persists in response to natural and anthropogenic changes at levels capable of providing a recreational fishery. Specific population objectives are identified with supporting management actions, believed to be critical to achieve population objectives.

A long history of fish stocking has occurred throughout the Big Lost watershed to provide more opportunities for anglers. Current regulations state that the MWF limit is zero, whereas the limit for trout is six from the Saturday of Memorial Day weekend through November 30, and the trout limit is zero for the rest of year.

OBJECTIVES

Estimate abundance, distribution, and size structure of the trout and MWF populations in the Big Lost River watershed.

Compare results from the current survey to prior surveys and evaluate effectiveness of prior management actions.

METHODS

We conducted mark-recapture population estimates on all trout species and MWF encountered in main-stem Big Lost River sample reaches. Due to increased flows, we used two electrofishing rafts rather than a canoe electrofishing setup, which was historically used in main-stem reaches. Water temperature (°C) and conductivity (µS/cm) were taken prior to electrofishing using a handheld probe. Pulsed direct current was provided by a 5000-W generator and standardized to 2,750-3,250 W based on water conductivity (Miranda 2009). Electricity was applied to the water using an Infinity-model electrofisher (Midwest Lake Management, Inc., Polo, Missouri). Electrofishing began at the uppermost point of the sampling reach and proceeded in a downstream direction. One netter was positioned at the bow of the raft and used a 2.4-m long dip net with 6-mm bar knotless mesh. Netters were instructed to net all trout and MWF and place fish into an aerated live well that was located in the raft. All fish were identified to species and measured for total length (TL) to the nearest mm and the mean was calculated for each species. All trout greater than or equal to 150 mm and all MWF greater than or equal to 200 mm were marked with a hole punch in the caudal fin prior to release. Fish were not marked during the recapture effort, but all fish previously marked were recorded as such. We estimated densities for all trout ≥ 150 mm using the Log-likelihood method in Fisheries Analysis+ software (FA+; Montana Fish, Wildlife, and Parks 2004) if there were adequate sample sizes per size class. If we had limited recaptures, we used the Peterson estimate with the Chapman modification for population estimates. We calculated 95% CI for each estimate. Mark-recapture estimates were conducted in the main-stem Big Lost River upstream of Mackay Reservoir at the Bartlett Point reach, and downstream of Mackay Reservoir at the Campground and Leslie reaches.

In the upper Big Lost River tributaries, we used backpack electrofishing units to sample most sites (n = 28), but also used a canoe electrofishing unit (see Garren et al. 2010) to sample four of the larger tributaries in the North Fork (n = 2) and East Fork (n = 2). We repeated sample reaches from past years where possible. Where this was not possible due to logistical constraints and safety issues such as unpassable diversions, we selected sampling reaches to capture spatial and/or major landscape characteristics such as sampling major tributaries. Reach lengths were between 100 and 300 m, and reaches began and ended at a riffle or other break in habitat types. Two- to four-pass depletion estimates were conducted in each reach to estimate fish density and abundance. Density estimates (fish per 100 m^2) were calculated and compared to previous years to evaluate trends.

We followed the methods described in Garren et al. (2009) to estimate the abundance and distribution of MWF throughout the Big Lost River watershed. Specifically, we report the density of MWF $\geq$ 200 mm/km and the number of MWF per reach (i.e., the estimate upstream and downstream of Mackay Reservoir, and in the tributaries of the Big Lost River) as described in the management plan. If two sites were sampled in a management reach (e.g., downstream of Mackay Reservoir included two sites; Big Lost River at Campground and at Leslie), then we used the average of the sites for the abundance estimate. We used those estimates to evaluate the status of MWF in relation to the management objectives outlined in the management plan for MWF in the Big Lost River basin (IDFG 2007).

To examine overwinter survival of juvenile fish (i.e., age-0), we stocked adipose-clipped YCT in October 2016 at three locations. We stocked approximately 20,000 fingerlings at each section in the East Fork, North Fork, and main-stem of the Big Lost River upstream of Mackay

Reservoir. The number of adipose-clipped fish collected in the summer electrofishing surveys was used to provide a general index of the overall winter survival and growth of fingerlings.

We examined streamflow from the North Fork Big Lost River at Wildhorse (USGS 13120000) by season (March 1, 2000 to May 30, 2018). Seasons were delineated as winter (December, January, February), spring (March, April, May), and summer (June, July, August).

RESULTS

Mountain Whitefish Distribution and Abundance

We sampled MWF at six of our standardized sites. In the North Fork Big Lost River downstream of Deep Creek, we sampled 4 MWF (1 fish ≥200 mm) and estimated 0.03 fish/km, which equates to 10.5 fish for the North Fork reach (i.e., 30.6 km; Table 12). In the East Fork Big Lost River we estimated 2.1 fish/km and 62 fish in the management reach (29.7 km). In the main-stem Big Lost River at Bartlett Point, we estimated 99 fish/km in the population estimate equating to 2,449 fish in the management reach (24.7 km). In the main-stem Big Lost River at the Campground and Leslie reaches we estimated 18 and 122 fish/km, respectively. These two sites averaged together and extrapolated result in an estimate of 2,274 fish in the management reach (32.6 km).

Leslie

We marked fish on April 19 and conducted the recapture run on April 23. We collected 289 fish in the Leslie reach of the Big Lost River. Species composition consisted of 50% RBT, 28% MWF, and 23% BKT. The TL of RBT ranged from 132 to 529 mm and averaged 355 mm, MWF ranged from 130 to 355 mm and averaged 275 mm, and BKT ranged from 107 to 356 mm and averaged 233 mm (Figure 31). We estimated 272 RBT for the reach (i.e., 173 per km, ± 33; 95% CI), 174 MWF ≥ 200 mm (i.e., 122 per km, ± 15), and 164 BKT ≥ 150 mm (i.e., 104 per km, ± 15; Tables 13-15).

Campground

We marked fish in the Campground reach on April 16 and conducted the recapture run on April 18. We collected 468 fish in the Campground reach of the Big Lost River for the population estimate. Species composition was 98% RBT, 3% MWF, and <1% kokanee. Rainbow Trout ranged from 123 to 590 mm with an average TL of 376 mm (Figure 32) and MWF ranged from 270 to 452 mm with an average TL of 377 mm (Figure 33). We estimated 1,156 RBT ≥ 150 mm and 1,027 per km (± 127; Figure 34). For MWF (≥ 200 mm), we estimated a total of 20 fish for the reach and 18 per km (± 2; Table 12).

Bartlett Point

We sampled the Bartlett Point site with two electrofishing rafts; marking fish on August 29 with two marking runs and recapturing fish on August 30. We collected 201 fish in the Bartlett Point reach of the Big Lost River. Species composition was 39% MWF, 35% RBT, 26% YCT, and <1% Arctic Grayling and BKT. About 1% of fish sampled in the reach were hybrid (Rainbow x Cutthroat) trout. Hybrid trout were included with RBT in the overall species composition, the population estimate, and the length-frequency distribution. Mountain Whitefish ranged from 82 to 433 mm and averaged 298 mm (Figure 35). Rainbow Trout ranged from 119 to 521 mm and averaged 292 mm. Yellowstone Cutthroat Trout ranged from 175 to 465 mm and averaged 330 mm. We estimated 320 MWF ≥ 200 mm (i.e., 99 per km, ± 26; Table 13), 287 RBT ≥ 150 mm (i.e., 89 per km, ± 23), and 213 YCT (i.e., 66 per km, ± 17; Table 12).

Lower North Fork (Mouth to Summit Creek)

We collected 10 salmonids during a two-pass depletion estimate in the lower North Fork of the Big Lost River. Species composition was 40% RBT, 40% MWF, 10% YCT, and 10% BKT. We estimated salmonid densities in the lower North Fork at 0.3 fish per 100 m^2, (0.14 fish per 100 m^2; Table 14) compared to 2012 (0.32 fish per 100 m^2). Rainbow Trout ranged in size from 145 to 429 mm (mean = 335 mm) with 25% of fish less than 150 mm. The BKT and YCT were 130 and 401 mm, respectively. The density of MWF ≥ 200 mm was estimated at 0.03 fish per 100 m^2. MWF ranged from 80 to 435 mm (mean = 172 mm).

Middle North Fork (Bartlett Creek to Grasshopper Creek)

We collected 35 trout in two electrofishing depletion passes on the middle reach of the North Fork Big Lost River. Species composition was 86% BKT and 14% YCT. Trout density estimates were 1.28 fish per 100 m^2 and the density of trout ≥150 mm was estimated at 0.37 fish per 100 m^2. Brook Trout ranged in size from 59 to 254 mm (mean = 140 mm), with 73% of BKT measuring less than 150 mm. Yellowstone Cutthroat Trout densities were 0.17 per 100 m^2. Yellowstone Cutthroat Trout ranged from 72to 294 mm (mean = 203 mm). The presence of age-0 YCT indicates that some natural recruitment is occurring. No MWF were captured in 2017.

Upper North Fork

We collected 8 BKT in a three-pass depletion estimate in the upper North Fork. This reach was dominated by BKT with densities estimated at 0.44 trout per 100 m^2. Brook Trout ranged from 58 to 190 mm, with 75% estimated to be juvenile fish. No MWF were captured.

Summit Creek (Downstream of Phi Kappa Campground)

We collected 37 trout in a three-pass depletion estimate on Summit Creek. Species composition was 82% BKT and 18% RBT. We estimated 2.4 trout per 100 m^2 in 2017 and density of trout ≥150 mm was 0.9 fish per 100 m^2. Brook Trout TL ranged from 116 to 220 mm (mean =

159 mm), with 54% of fish measuring less than 150 mm. The TL of RBT ranged from 87 to 186 mm (mean = 129 mm), with 67% of RBT measuring less than 150 mm. No MWF were captured.

Kane Creek

We collected 23 trout in a two-pass depletion estimate in Kane Creek. Species composition was 96% BKT and 4% RBT. The trout density was 1.8 trout per 100 m^2 and the density of trout ≥150 mm were 0.4 fish per 100 m^2. Brook Trout ranged in size from 50 to 228 mm (mean = 132 mm), with 76% of those fish less than 150 mm. The only RBT captured was 82 mm. No MWF were captured.

Wildhorse Creek

We collected 345 salmonids in two separate reaches of Wildhorse Creek. Species composition was 98% BKT, 1% RBT, and <1% YCT. The trout density in the lower reach was 1.14 fish per 100 m^2, in the upper section trout density was 8.2 fish per 100 m^2. The density of trout ≥150 mm in the lower reach decreased was 0.7 fish per 100 m^2, in the upper reach density of trout ≥150 mm was 2.0 fish per 100 m^2. In the lower reach, BKT ranged in size from 102 to 256 mm (mean = 152 mm), with 58% of those fish measuring less than 150 mm. RBT in the lower reach ranged in size from 85 to 339 mm (mean = 275 mm) with one RBT less than 150 mm. In the upper reach, the TL of BKT ranged from 34 to 258 mm (mean = 111 mm). One RBT (TL = 240 mm) was sampled in the upper reach of Wildhorse Creek. No MWF were collected.

Fall Creek

We collected four salmonids in a two-pass depletion estimate in Fall Creek. Species composition was 100% BKT. Trout density was 0.7 fish per 100 m^2 and the density of trout ≥150 mm was estimated at 0.13 fish per 100 m^2 in 2017. The TL of BKT ranged from 110 to 182 mm (mean = 132). No MWF were sampled in 2017.

Lower East Fork

We collected 95 salmonids in two electrofishing reaches using a canoe electrofishing unit in the lower East Fork (i.e., East Fork at Whitworth and at Fox Creek). Species composition was 47% BKT, 28% YCT (8% were estimated to be hatchery origin), 13% MWF, and 9% RBT. Trout density was estimated at 1.2 fish per 100 m^2 at Whitworth and 2.0 fish per 100 m^2 at Fox Creek. Density of trout ≥150 mm in the Whitworth reach was 0.5 in 2017, and the density of MWF ≥ 200 mm was 0.4 fish per 100 m^2. In the Fox Creek reach, the density of trout ≥150 mm was 1.1 fish per 100 m^2 and one MWF (86 mm) was collected. Arctic Grayling were sampled at Whitworth and Fox Creek, however at low densities of 0.04 and 0.02 fish per 100 m^2, respectively. The Arctic Grayling were 305 and 312 mm. Brook Trout ranged in size from 95 to 275 mm (mean = 184 mm), with 16% of those BKT measuring less than 150 mm. MWF ranged in size from 86 to 421 mm (mean = 242 mm), with 1% measuring less than 200 mm. Yellowstone Cutthroat Trout ranged in size from 111 to 358 mm (mean = 204 mm), with 56% measuring less than 150 mm. Rainbow

Trout ranged in size from 134 to 380 mm (mean = 218 mm), with 22% measuring less than 150 mm.

Upper East Fork

We collected 144 trout in two reaches of the upper East Fork (i.e., East Fork at Burma and East Fork at the Swamps). We estimated the trout density in the Burma reach at 16.6 fish per 100 m^2. In the Burma reach, species composition was 46% RBT, and 54% BKT. Trout density ≥150 mm in this reach was 11.0 fish per 100 m^2. Rainbow Trout ranged from 116 to 337 mm (mean = 280 mm) and the majority of these fish were thought to be of hatchery origin. Brook Trout ranged in size from 56 to 279 mm (mean = 125 mm), with 11% of those fish less than 150 mm.

In the Swamps reach, BKT were the only salmonid captured, and their density was 8.5 fish per 100 m^2. We estimated 3.7 BKT ≥150 mm per 100 m2. Brook Trout ranged in size from 74 to 179 mm (mean = 126 mm), with 50% of those fish less than 150 mm. No MWF were captured at either site.

Lower Star Hope Creek (West Fork Big Lost River)

We collected 14 trout in the lower Star Hope reach (above the bridge on FR 135) and 58 trout in the middle Star Hope (Cow Camp) reach. Species composition in the lower reach was 64% BKT and 46% YCT. Trout density at the lower site was estimated at 0.2 fish per 100 m^2 and the density of trout ≥150 mm was 0.1 fish per 100 m^2. In the survey at the lower site, BKT ranged in size from 74 to 211 mm (mean = 129 mm) with 38% of those fish less than 150 mm. Yellowstone Cutthroat Trout ranged in size from 38 to 353 mm (mean = 234 mm) with 40% of those fish less than 150 mm.

Species composition in the middle reach was 86% BKT, 12% YCT, and 2% Arctic Grayling. We estimated trout density at 3.1 fish per 100 m^2 for the middle reach. The density of trout ≥150 mm in the middle reach was 0.6 fish per 100 m^2. In the middle reach, BKT ranged in size from 43 mm to 236 mm (mean = 114 mm), with 72% of those fish less than 150 mm in length. The YCT ranged in size from 35 to 392 mm (mean = 95 mm) with 86% of those fish less than 150 mm. The only Arctic Grayling captured was 314 mm. No MWF were captured in either reach.

Upper Star Hope Creek (West Fork Big Lost River – Loop Road)

We collected 36 trout during a three-pass depletion estimate in the upper Star Hope Creek reach. Species composition was 63% YCT and 37% BKT. We estimated that 95% of the YCT captured were of hatchery origin. The trout density was 2.2 fish per 100 m^2, and the density of trout ≥150 mm was 1.4 fish per 100 m^2. Brook Trout ranged in size from 96 mm to 180 mm (mean = 126 mm) with 64% of those fish measuring less than 150 mm. YCT ranged in size from 113 to 360 mm (mean = 306 mm). No MWF were captured in this reach.

Broad Canyon Creek

We collected 22 trout in a two-pass depletion estimate in Broad Canyon Creek and species composition was 100% BKT. Trout density was 2.9 fish per 100 m^2 and the density of trout ≥150 mm was 0.7 fish per 100 m^2. Brook Trout ranged in TL from 36 to 200 mm (mean = 108 mm) with 77% of those fish measuring less than 150 mm. No MWF were captured in this reach.

Muldoon Canyon Creek

We collected 61 trout in a four-pass depletion estimate in Muldoon Canyon Creek. Species composition was 52% BKT and 48% YCT, which we estimated as all hatchery origin. Trout density was estimated at 6.4 trout per 100 m^2, and the density of trout ≥150 mm was estimated at 3.6 fish per 100 m^2. Brook Trout ranged in TL from 41 to 203 mm (mean = 113 mm) with 72% of those fish less than 150 mm. Yellowstone Cutthroat Trout ranged from 270 to 376 mm (mean = 326 mm). No MWF were captured in this reach.

Lake Creek

We collected 87 trout in a two-pass depletion estimate in Lake Creek. Species composition was 93% BKT, 6% YCT, and 1% Arctic Grayling. Trout density was estimated at 8.1 fish per 100 m^2, and the density of trout ≥150 mm was estimated at 2.4 fish per 100 m^2. Brook Trout ranged in size from 80 mm to 231 mm (mean = 116 mm) with 73% of BKT less than 150 mm. Yellowstone Cutthroat Trout ranged in size from 299 to 362 mm (mean = 322 mm). The only Arctic Grayling captured was 138 mm. No MWF were captured in this reach.
Antelope Creek (Lower, Middle, and Upper reaches)

We collected 57 trout in three electrofishing reaches in Antelope Creek. Species composition was 93% BKT and 7% RBT. Trout density was estimated at 1.0 fish per 100 m^2 and was highest in the upper sampling reach at 2.0 fish per 100 m^2. Density of trout ≥150 mm was estimated to be 0.5 fish per 100 m^2. Brook Trout ranged in size from 45 to 295 mm (mean = 161 mm), with 54% of those fish less than 150 mm. Rainbow Trout ranged in size from 127 to 313 mm (mean = 221 mm), with 25% of RBT less than 150 mm. No MWF were captured.

Cherry Creek

We collected 86 trout in a three-pass depletion estimate in Cherry Creek. Species composition was 92% BKT and 8% RBT. Trout density was 24.9 fish per 100 m^2, and the density of trout ≥150 mm was estimated at 7.6 fish per 100 m^2. Brook Trout ranged in size from 63 to 226 mm (mean = 138 mm), with 73% of those fish less than 150 mm. Rainbow Trout ranged in size from 110 to 222 mm (mean = 160 mm), with 43% of RBT less than 150 mm. No MWF were captured.

Iron Bog Creek

We collected four trout in a two-pass depletion estimate in Iron Bog Creek. Species composition was 100% BKT. Trout density was 0.5 fish per 100 m^2, and the density of trout ≥150 mm was estimated at 0.4 fish per 100 m^2. Brook Trout ranged in size from 101 to 217 mm (mean = 170 mm), with 25% of BKT less than 150 mm. No MWF were captured.

Overwinter Survival

We sampled 20 sites in the main-stem of the Upper Big Lost River above Mackay Reservoir. We were unsuccessful in collecting any adipose-clipped YCT in 2017.

DISCUSSION

Basin-wide trout abundance estimates from 2017 to 2018 are lower than estimates during 2003-2012. But, trout densities were slightly higher in a few locations, including the upper site in Wildhorse Creek, Fall Creek, and Muldoon Canyon Creek. In most tributaries, abundance and density estimates have declined from a peak observed in 2007. However, the results of these studies may be confounded by several factors. After 2007, there was a shift in stocking practices in the basin, which may have contributed to declines in trout abundance at our standardized sites. For example, we stopped stocking trout in Antelope Creek in 2007. Also, in the Copper Basin area we switched from Troutlodge-strain to Hayspur-strain RBT, and we stocked over 11,000 YCT fingerlings in early May of 2007 in the East Fork Big Lost River. Fewer stocked fish in recent years likely contributed to lower density estimates at our standardized sites. Furthermore, changes in crew and electrofishing technology may have further confounded the trends observed. For example, the Campground reach on the Big Lost was historically electrofished using a canoe electrofishing unit, which was more effective at sampling juvenile trout; but in 2017-2018 due to higher flows than historical estimates, we used two raft electrofishing units in the main-stem Big Lost River sampling sites. Our estimate for that reach lacks an entire year class of juvenile fish that likely reduced our overall abundance estimate. Unfortunately, due to gear differences among years, we cannot determine whether changes in overall abundance were caused by gear-associated biases or whether a juvenile year class was truly absent.

We found the first known observation of the Arctic Grayling within lotic waters of the Big Lost River basin. Most likely, Arctic Grayling originated from mountain lakes (e.g. Round Lake) stocked for recreational angling. Abundances of Arctic Grayling were low (0.02 to 0.04 fish per 100 m^2), but were found at four different sites suggesting Arctic Grayling occupy a small portion of the drainage currently. No juvenile Arctic Grayling were collected, so as of yet we have no evidence of natural reproduction. Possible competitive interactions between Arctic Grayling and native MWF populations may need to be examined if Arctic Grayling expand and establish a self-sustaining population in the riverine environment; however, little to no research has been conducted exclusively on the interactions between Arctic Grayling and MWF (Northcote and Ennis 1994; Meyer et al. 2009).

The fact that we did not sample adipose-clipped YCT stocked as age-0s in the main-stem Big Lost River after winter may indicate habitat limitations for survival of juvenile trout. In contrast, we did sample YCT less than 150 mm at some of our sampling reaches (e.g., East Fork Big Lost River). The lack of adipose-clipped YCT may be partially explained by high spring flows prior to sampling which may have transported proportion of these juveniles downstream out of the sampling reach. Because we sampled wild Cutthroat Trout in some reaches, but not in the main-stem suggests that wild-origin trout may have better survival than hatchery-origin fingerlings. Therefore, the use of hatchery-origin fingerlings was a limitation to gaining a better understanding of overwinter survival and habitat limitation. Future efforts should focus on utilizing wild fish for this sort of assessment. Spring flows were the second highest in the past 20 years and summer flows were the highest in the past 20 years. High spring and summer flows may have affected our efficiency at capturing smaller-sized trout, and juvenile fish may have been in tributaries or moved downstream as a result of high flows. Another possibility is the lack of canopy cover on portions of streams in the Copper Basin where the dominant vegetation in the riparian corridor is sagebrush, grasses, and willows. Due to lack of canopy cover, the streams may have extreme temperature fluctuations throughout the year and streams may accumulate frazil and anchor ice during the winter, which can be very detrimental to localized salmonid populations (Brown et al. 2011). More research on overwintering habitat and flow regimes is necessary to evaluate the effect these factors have on salmonid abundance in the upper basin.

Stocking YCT, which began in 2000, continues to supplement the existing RBT and BKT fishery in the Upper Big Lost River, and these fish have now migrated throughout the drainage. It was previously suspected that whirling disease may be suppressing trout populations, and that Cutthroat Trout may be more resistant to infections. Stockings have only occurred in the West Fork, but Cutthroat Trout are now found throughout the entire Big Lost River Drainage, down through Mackay Reservoir and downstream as far as Antelope Creek. Natural reproduction is occurring, and has lead to Cutthroat Trout becoming a significant component to the fishery. The persistence of all three trout species in the drainage and the abundance of juvenile fish encountered during the past decade suggest that whirling disease, which was suspected to have population level effects in the 1990s, is currently not impacting the population substantially. It's probable that population-level fluctuations are more likely tied to environmental conditions such as flows or other unidentified pathogens besides whirling disease.

Mountain Whitefish populations in the Big Lost River have increased in abundance in some locations (Big Lost River at Leslie, Bartlett, and East Fork Big Lost at Whitworth) compared to older population estimates, but in most instances, abundance remains below recent highs documented in the 1980s. The locations where MWF abundance has increased since 2012 surveys were in reaches with a wider wetted width, which corresponds to other Idaho waters (Meyer and Elle 2009). In their assessment, MWF were present more often in streams with a wetted width greater than 10 m. We found MWF at two tributary sites (North Fork and East Fork Big Lost), and in all three main-stem sites. The density of MWF has increased at the Bartlett site from levels in 2002 and 2005, and densities remain similar at the campground and Leslie reaches in the main-stem below Mackay Dam. Overall, it appears that MWF are persisting throughout the Big Lost drainage, and populations appear to be more abundant than they were a decade ago. A watershed-wide barrier assessment was conducted between 2004-2008 on diversions throughout the Big Lost River basin (Kennedy 2009; Gregory 2018). Following this assessment, various agencies and conservation entities cooperated to improve these barriers by adding fish ladders on diversions where migration was prohibited to improve fish passage and ultimately the distribution of MWF.

Despite these efforts, the management objectives as outlined in the Conservation plan (IDFG 2007), are not being met. The management plan (IDFG 2007) calls for two metapopulations of 5,000 MWF each, upstream and downstream of Mackay Reservoir. Upstream of Mackay Reservoir we observed MWF in two tributaries (East Fork and North Fork) of the Big Lost River and in the main-stem. We are nearly meeting the management objective, which calls for presence in three tributaries, in addition to the main-stem. Downstream of Mackay Dam, we are not meeting all of the management objectives. Mountain Whitefish are currently distributed from the Blaine Diversion to Mackay Dam, but their abundance is less than 5,000 fish. As of this assessment we do not know the abundance of MWF between the Blaine and Moore diversions, but we do know that they are present in this reach. Furthermore, we did not detect MWF in our standardized sites in Antelope Creek.

Fish salvage efforts in canals of the Big Lost River began in 2004 and continue on an annual basis. From 2004 to 2018 and with the help and cooperation of the U. S. Forest Service (USFS), a total of 12,783 MWF have been translocated (USFS, unpublished data) into the main-stem Big Lost upstream of Mackay Reservoir and its tributaries. This effort supports the objectives of the Big Lost MWF Management Plan (IDFG 2007) by translocating whitefish entrained in canals into reaches where we are trying to maintain the distribution and abundance of Mountain Whitefish. The canals and diversions upstream of Mackay Reservoir have been assessed and deemed passable for fish at most water levels (Gregory 2018), but due to sinks and diversions we need to continue our fish salvage efforts in the main-stem near the Chilly Diversion. Although fish salvage efforts continue, entrainment continues to be a limiting factor for the distribution and abundance of Mountain Whitefish in the Big Lost watershed. Additionally, whirling disease has been detected in the East Fork Big Lost River (Elle 1997), and it is known to increase mortality rates of Mountain Whitefish fry (Schisler 2010).

Given the limiting factors of entrainment, fish passage, and disease we have several recommendations to help mitigate these factors. We recommend conducting additional sampling between the Blaine and Moore diversions and more sites on Antelope Creek to more accurately estimate the abundance of MWF in these locations. When feasible, we recommend conducting fish salvage efforts between the Blaine and Moore Diversions and to collaborate with the USFS to conduct salvages near the Chilly Diversion. We also recommend continuing to work with the Lost River Irrigation District by recommending flows to maintain fish passage at diversions. Disease is a potential limiting factor that has not been investigated downstream of Mackay Reservoir. We recommend conducting sentinel fish studies downstream of Mackay Reservoir in the Big Lost River to develop a baseline understanding of disease distribution in the river and how that may be limiting the Mountain Whitefish population.

RECOMMENDATIONS

1. Continue to estimate drainage-wide abundances of MWF as possible. Design future studies to address total abundance of MWF by sampling additional reaches where MWF were historically distributed.

2. Continue fish salvage efforts upstream and downstream of Mackay Reservoir to aid MWF survival, abundance, and distribution.

3. Periodically monitor trout populations and angler use in the Big Lost River above Mackay Dam to evaluate natural reproduction, distribution, and contribution to the fishery.

4. Quantify harvest and natural mortality upstream and downstream of Mackay Dam.

5. Estimate fry abundance and overwinter survival of fry upstream and downstream of Mackay Dam.

6. Assess instream winter habitat conditions for salmonids.

Table 12. Trout and Mountain Whitefish population estimate summary from the main-stem Big Lost River at sampling sites during 2017 (Barlett Point) and 2018 (Campground and Leslie). (ARG = Arctic Grayling; BKT = Brook Trout, MWF = Mountain Whitefish, RBT = Rainbow Trout, YCT = Yellowstone Cutthroat Trout).

River reach	Species	No. marked	No. captured	No. recaptured	Population Estimate	Confidence Interval (+/- 95%)	Density (No./ km)	Discharge (cfs)[a]
Leslie	BKT	54	23	7	164	99–326	104	234[c]
	MWF	47	27	6	191	107–403	122	
	RBT	132	36	17	272	220–324	173	
Campground	MWF	5	5	2	11	6–27	10	290[c]
	RBT	320	215	74	1,162	1,016–1,308	1,032	
Bartlett Point	ARG	1	1	0	--	--	--	230[b]
	BKT	1	1	0	--	--	--	
	MWF	56	31	9	251	102–400	78	
	RBT[d]	50	24	5	287	183–808	111	
	YCT	34	18	0	213	134–591	82	

[a] Represents the mean discharge value between marking and recapture events.
[b] Data obtained from USGS gauge (13120500) at Howell Ranch near Chilly.
[c] Data obtained from USGS gauge (13127000) below Mackay Reservoir near Mackay.
[d] Combined RBT and YCT for estimate.

Table 13. Salmonid densities found in the Big Lost River, Idaho during 2017 and 2018 electrofishing samples for Rainbow Trout (RBT), Brook Trout (BKT), Mountain Whitefish (MWF), Yellowstone Cutthroat Trout (YCT), and Arctic Grayling (ARG).

				Density (number of fish ≥150 mm per 100 m^2)					
Location	Drainage	Reach length (m)	All salmonids	All trout	RBT	BKT	MWF	YCT	ARG
Big Lost at Bartlett Point	Main	3,228	--	0.95	0.54	0.01	0.60	0.40	0.01
Lower North Fork	North	300	0.34	0.14	0.10	0.00	0.03	0.03[b]	0.00
Mid North Fork	North	300	1.28	0.37	0.00	0.27	0.00	0.10	0.00
Upper North Fork	North	311	0.44	0.11	0.00	0.11	0.00	0.00	0.00
Summit Creek	North	300	2.37	1.01	0.13	0.87	0.00	0.00	0.00
Kane Creek	North	208	1.83	0.38	0.00	0.38	0.00	0.00	0.00
Lower Wildhorse Creek	East	197	1.14	0.74	0.42[b]	0.26	0.00	0.05	0.00
Upper Wildhorse Creek	East	300	8.19	2.04	0.03	2.02	0.00	0.00	0.00
Fall Creek	East	113	0.65	0.13	0.00	0.13	0.00	0.00	0.00
Lower East Fork (Whitworth)	East	195	1.17	0.53	0.19	0.11	0.42	0.23[b]	0.04
Lower East Fork (Fox Creek)	East	380	1.99	0.72	0.05	0.58	0.00	0.10[b]	0.02
East Fork @ Burma	East	171	16.55	10.99	7.41	3.58	0.00	0.00	0.00
East Fork @ Swamps	East	72	8.45	3.70	0.00	3.70	0.00	0.00	0.00
Lower Star Hope Creek	West	485	0.19	0.09	0.00	0.05	0.00	0.04	0.00
Mid Star Hope Creek (Cow Camp)	West	244	3.09	0.57	0.00	0.53	0.00	0.04	0.04
Upper Star Hope Creek	West	266	2.21	1.44	0.00	0.18	0.00	1.26[b]	0.00
Broad Canyon Creek	West	164	2.94	0.67	0.00	0.67	0.00	0.00	0.00
Muldoon Creek	West	150	6.41	3.38	0.00	0.80	0.00	2.58	0.00
Lake Creek	West	208	8.12	2.37	0.00	1.93	0.00	0.44	0.00
Lower Antelope Creek	Antelope	190	0.71	0.47	0.12	0.36	0.00	0.00	0.00
Middle Antelope Creek	Antelope	148	0.34	0.21	0.00	0.21	0.00	0.00	0.00
Upper Antelope Creek	Antelope	269	1.96	0.80	0.05	0.75	0.00	0.00	0.00

Table 13 (continued)

Location	Drainage	Reach length (m)	All salmonids	Density (number of fish ≥150 mm per 100 m^2) All trout	RBT	BKT	MWF	YCT	ARG
Cherry Creek	Antelope	127	24.90[a]	5.22	0.83	4.38	0.00	0.00	0.00
Iron Bog Creek	Antelope	120	0.50	0.38	0.00	0.38	0.00	0.00	0.00
Alder Creek	Lower BL	100	12.21	1.41	0.00	1.41	0.00	0.00	0.00
Pass Creek	Lower BL	100	13.86	7.08	0.00	7.08	0.00	0.00	0.00

[a] - Includes hybrid (rainbow x cutthroat) trout
[b] – Includes hatchery trout

Table 14. Density estimates (fish per 100 m^2) for historic sample reaches of the Big Lost River, Idaho. Estimates were means for a given stream when more than one site was sampled in a given year.

Location	Drainage	Sample Year	Density (number of fish ≥150 mm/ 100 m^2)			
			All salmonids	Trout	RBT	BKT
Lower Big Lost River Main-stem	Main	1987[a]	--	16.71	16.71	0.0
		1991	--	7.55	6.72	0.83
		2002	--	8.04	7.02	1.02
		2007	--	6.66	5.76	0.90
		2012	--	10.42	8.49	1.91
		2017	--	3.53	3.14	0.39
Upper Big Lost River Main-stem	Main	1988	1.41	1.29	1.18	0.11
		1990	1.23	1.10	1.08	0.02
		2003	1.15	0.43	0.37	0.06
		2007	0.03	0.0	0.0	0.0
		2012	--	0.79	0.41	0.01
		2017	--	0.95	0.54	0.01
North Fork Big Lost River	North Fork	1986	13.23	1.76	0.33	1.43
		1996	14.70	8.35	0.50	7.85
		2003	2.07	1.33	0.94	0.39
		2007	14.06	0.92	0.42	0.46
		2012	2.39	0.86	0.07	0.70
		2017	0.64	0.21	0.03	0.13
Summit Creek	North Fork	1986	27.15	5.75	0.25	5.45
		1996	11.75	10.45	0	10.45
		2003	14.40	4.73	0.68	4.05
		2007	28.87	8.16	0.80	7.35
		2012	5.73	2.15	0.40	1.75
		2017	2.19	1.01	0.13	0.87
Wildhorse Creek	East Fork	1986	4.35	0.55	0.15	0.40
		2003	3.12	0.95	0.12	0.83
		2007	7.03	3.95	0.44	3.44
		2012	4.82	1.71	0.07	0.94

Table 14 (continued)

Location	Drainage	Sample Year	Density (number of fish ≥150 mm/ 100 m^2)			
			All salmonids	Trout	RBT	BKT
		2017	4.58	1.39	0.22	1.14
Lower East Fork		1986	1.85	0.35	0.26	0.09
	East Fork	1990	1.46	1.46	0.73	0.73
		2003	3.01	1.92	1.28	0.64
		2007	5.19	3.64	1.77	1.76
		2012	1.63	0.90	0.26	0.43
		2017	1.56	0.63	0.12	0.34
Upper East Fork		1986	33.85	23.91	9.58	14.33
	East Fork	1996	9.05	9.05	3.35	5.70
		2003	24.5	12.70	2.10	10.60
		2007	31.62	18.63	2.63	14.61
		2012	26.82	18.47	0.68	13.62
		2017	12.43	7.34	3.71	3.64
West Fork (Star Hope Creek)	West Fork	1986	4.94	1.06	0.05	1.01
		2003	10.07	4.35	0.18	4.17
		2007	11.0	2.73	0.01	2.18
		2012	4.31	2.42	0	0.34
		2017	1.59	0.70	0	0.26
Muldoon Canyon Creek	West Fork	1986	9.70	2.90	0.10	2.80
		1996	4.25	3.62	0	3.62
		2003	19.4	4.05	0	4.05
		2007	21.25	3.02	0	2.29
		2012	5.05	0.20	0	0.20
		2017	6.50	3.38	0	0.80
Lake Creek	West Fork	1986	19.80	8.20	0.60	7.60
		1996	10.30	8.90	0	8.90
		2003	56.6	22.9	0	22.9
		2007	57.77	13.69	0	13.3
		2012	39.16	7.99	0	7.99
		2017	6.43	2.37	0	1.93

[a]1987 sample only included the Campground section, which is the highest density area for the lower main-stem reach.

Table 15. Mountain Whitefish abundance in the Big Lost River Drainage, Idaho as determined from electrofishing surveys. The 95% confidence intervals (CI) for each population estimate are in parentheses.

Location	Year sampled	Source	Length sampled (m)	Mean width (m)	Population estimate (No. fish ≥ 200 mm)	No. fish / 100 m^2	No. fish per km
Desert	1970's	Overton					
	2003	USFS	0[a]	0[a]	0[a]	0[a]	0[a]
Big Lost @ Arco	1987	IDFG	490	9.1	262 (198-365)	5.2	473
	2002	USFS	0[a]	0[a]	0[a]	0[a]	0[a]
Big Lost @ Blaine diversion	2009	IDFG+USFS	745	12.8	409 (402-414)	4.3	549
	2012	IDFG+USFS	745	12.1	344 (49-639)	3.8	462
Big Lost @ Leslie	1991	IDFG	4,000	15	48 (35-57)	0.1	12
	2002	IDFG	1,000	18	1[b]	<0.01[b]	1[b]
	2007	IDFG	1,000	18	70 (42-98)	0.4	70
	2018	IDFG	1,572	18	191 (107-403)	0.8	122
Big Lost @ Mackay	1987	IDFG	1,238	24.2	NE[c]	NE[c]	NE[c]
	1991	IDFG	800	37.4	280 (176-507)	0.9	350
	2002	IDFG	1,000	20.6	45 (27-64)	0.2	45
	2007	IDFG	944	17.0	61 (36-86)	0.4	65
	2012	IDFG+USFS	773	20.1	42 (27-82)	0.3	58
	2018	IDFG	1,140	22.3	11 (6-27)	0.04	10
Big Lost @ Bartlett Pt	1986	IDFG	1,500	13.4	285[d]	1.4[d]	190[d]
	1988	IDFG	2,239	17.0	423 (336-550)	1.1	189
	1990	IDFG	2,240	17.0	219	0.6	98
	1996	IDFG	3,001	19.9	1,322	2.2	441
	2003	IDFG+USFS	180	19.5	9 (8-15)	2.6	50
	2007	IDFG	158	19.1	1 (No CI's)	0.03	6.3
	2012	IDFG+USFS	3,228	16.5	446 (395-497)	0.84	138
	2017	IDFG+USFS	3,228	16.5	251 (102-400)	0.47	78
East Fork - Whitworth	1986	IDFG	1,243	13.8	825 (617-1,162)	4.8	664
	1990	IDFG	1,375	12.4	65	0.4	47.3
	1996	IDFG	924	12.4	84	0.7	91
	2003	IDFG+USFS	115	11.2	1	0.1	8.7
	2007	IDFG	119.5	13.2	41 (39-43)	2.6	343.1
	2012	IDFG+USFS	198	10.3	8 (5-11)	0.4	40.4

Table 15 (continued)

Location	Year sampled	Source	Length sampled (m)	Mean width (m)	Population estimate (No. fish ≥ 200 mm)	No. fish / 100 m^2	No. fish per km
	2017	IDFG+USFS	195	19.6	11 (10-12)	0.4	56.4
East Fork - Fox Creek	1986	IDFG	1,162	11.8	717 (549-977)	5.2	617
	1990	IDFG	1,209	11.3	51	0.4	43
	1996	IDFG	1,273	11.6	17[e]	0.1	14.2
	2003	IDFG+USFS	100	10.6	0	0	0
	2007	IDFG	149.5	9.7	0	0	0
	2012	IDFG+USFS	362	12.6	3 (3-6)	0.1	8.3
	2017	IDFG+USFS	380	13.5	0	0	0
West Fork – Bridge	1986	IDFG	1,364	16.1	1,480 (758-4,191)	6.7	1,085
	2003	IDFG+USFS	100	14.7	0	0	0
	2007	IDFG	211	15.4	0	0	0
West Fork – Cow Camp	1986	IDFG	1,440	10.5	344 (250-504)	2.2	239
	2003	IDFG+USFS	130	8.5	0	0	0
	2007	IDFG	122	9.0	0	0	0
	2012	IDFG+USFS	248	9.8	0	0	0
	2018	IDFG+USFS	244	10.7	0	0	0
North Fork – Forest Boundary	1986	IDFG	1,140	10.5	362 (281-485)	3.0	318
	2003	IDFG+USFS	300	8	0	0	0
	2007	IDFG	153	10	0	0	0
	2012	IDFG+USFS	328	9.4	4 (2-6)	0.1	12.2
	2018	IDFG+USFS	300	9.8	1 (No CI's)	<0.1	3.3
Wildhorse Cr (Lower section)	1986	IDFG	55	6	0	0	0
	2003	IDFG+USFS	200	10	0	0	0
	2007	IDFG	197	9	0	0	0
	2012	IDFG+USFS	197	10.3	0	0	0
	2017	IDFG+USFS	197	10.3	0	0	0
Wildhorse Cr (Upper Sect)	1986	IDFG	213	7	0	0	0
	2003	IDFG+USFS	200	7	0	0	0
	2007	IDFG	300	6.5	3 (No CI's)	0.2	10
	2012	IDFG+USFS	300	10.3	0	0	0

Table 15 (continued)

Location	Year sampled	Source	Length sampled (m)	Mean width (m)	Population estimate (No. fish ≥ 200 mm)	No. fish / 100 m^2	No. fish per km
	2017	IDFG+USFS	300	13.7	0	0	0
Antelope Cr – Wood Canyon	1987	IDFG	64	5.1	0	0	0
	1991	IDFG	569	6.7	0	0	0
	2003	USFS	200	5.9	0	0	0
	2007	IDFG	272	6.3	0	0	0
	2012	USFS	190	6.2	0	0	0
	2017	IDFG+USFS	190	8.9	0	0	0

[a] – Sampled, but no water present.
[b] – Numerous fry present, but not collected.
[c] – Whitefish present, but not estimated.
[d] – Only completed marking run. Figures presented are actual fish present, not a population estimate (would likely be higher).
[e] – No population estimate made – figures presented are actual fish present.

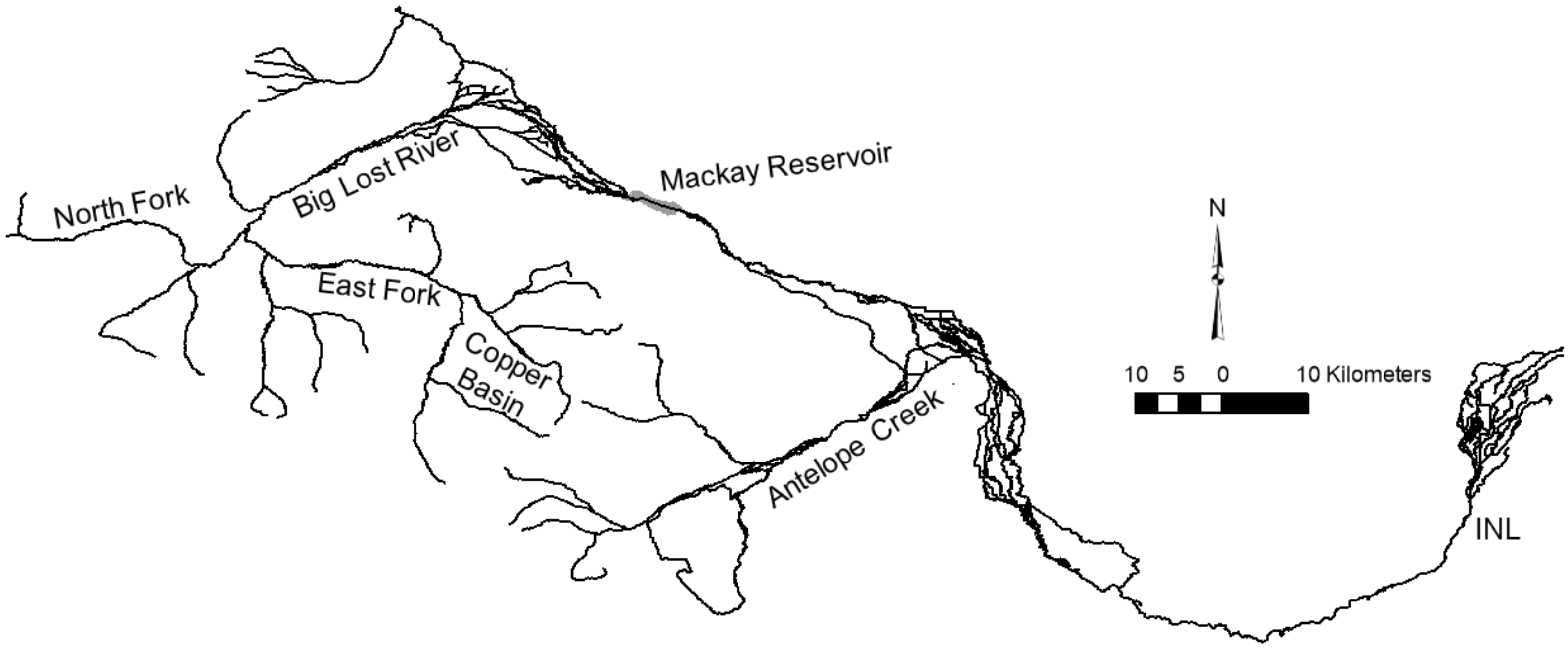

Figure 30. The Big Lost River watershed including streams in the Copper Basin area which join to create the main-stem Big Lost River. The Big Lost River then flows into Mackay Reservoir (in gray) then into the desert sinks near the Idaho National Laboratory (INL).

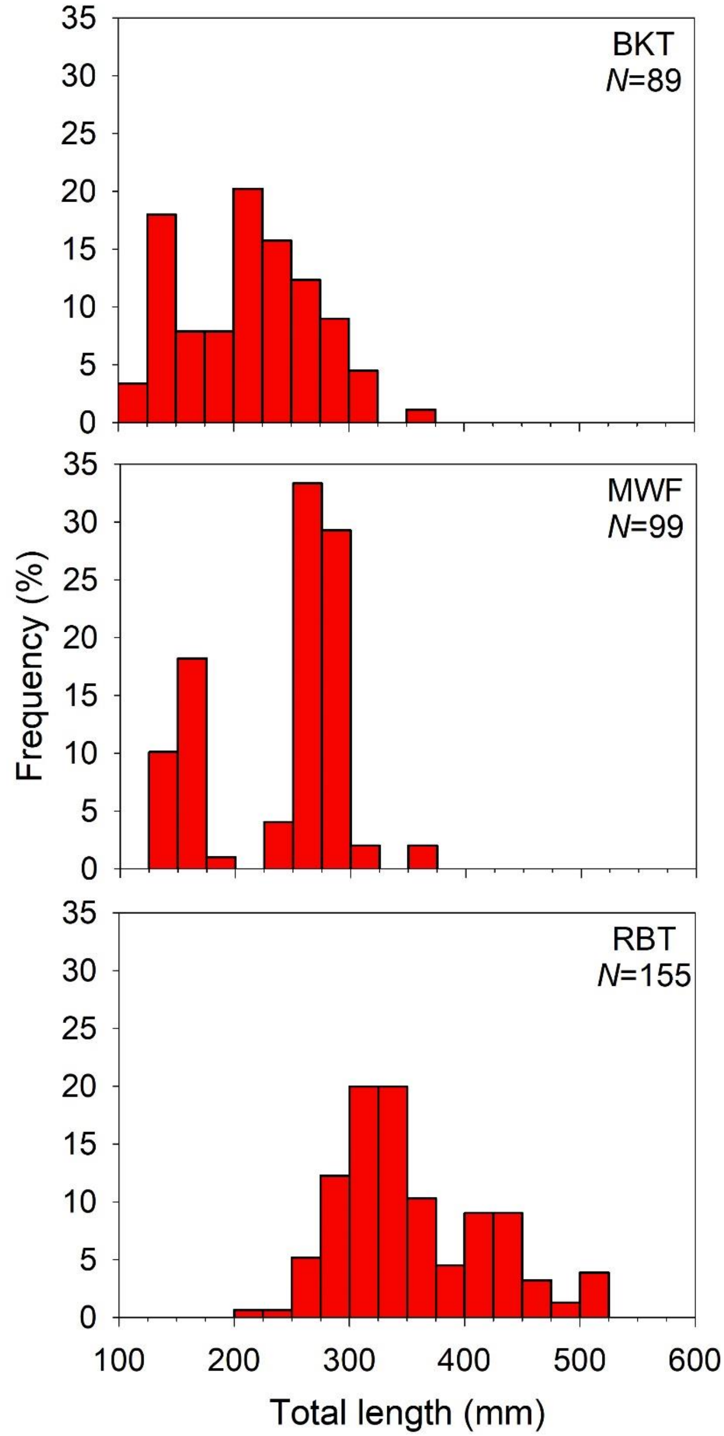

Figure 31. Length-frequency distribution of Brook Trout (BKT), Mountain Whitefish (MWF), and Rainbow Trout (RBT) collected in the Leslie reach of the Big Lost River, 2018.

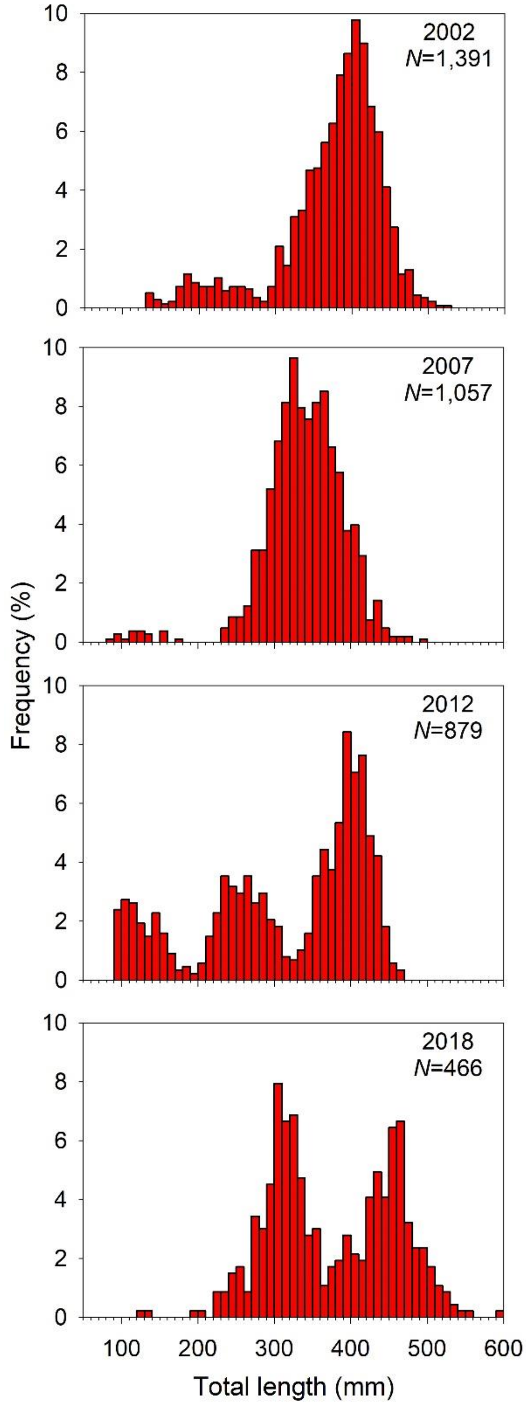

Figure 32. Length-frequency distribution of Rainbow Trout in the campground reach of the Big Lost River in 2002, 2007, 2012, and 2018.

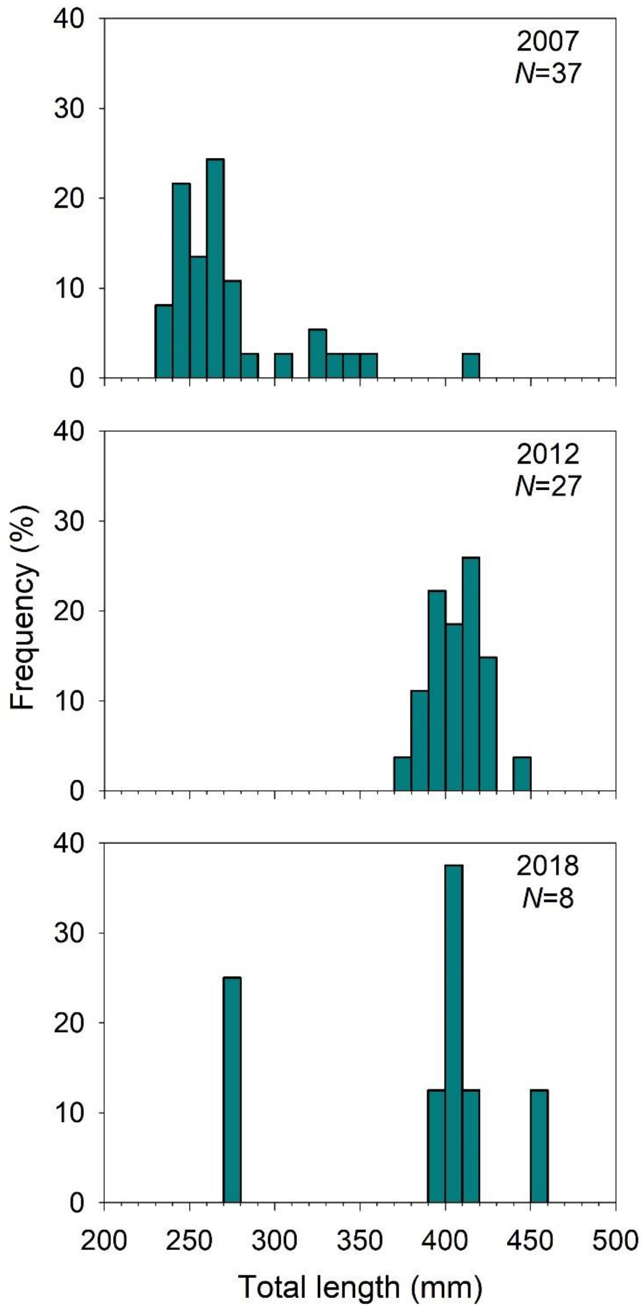

Figure 33. Length-frequency distribution of Mountain Whitefish in the campground reach of the Big Lost River in 2007, 2012, and 2018.

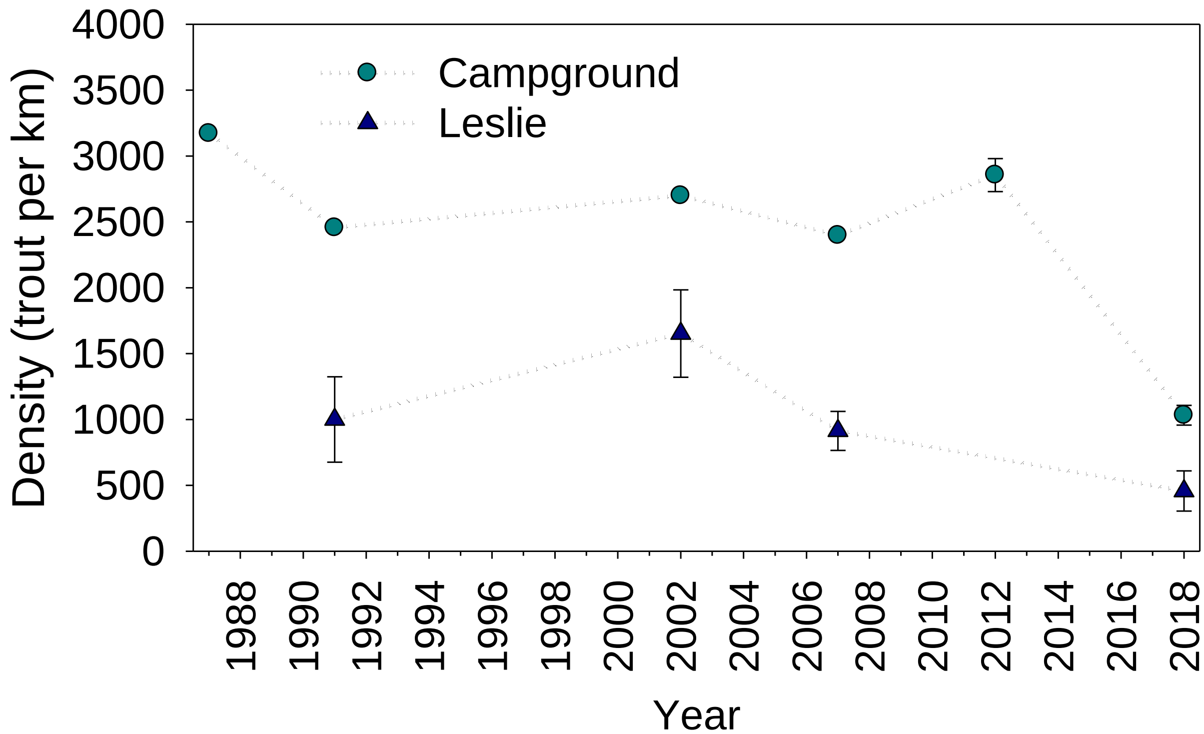

Figure 34. Log-likelihood method (LLM) density estimates of Rainbow Trout (per km) in Campground and Leslie reaches of the Big Lost from 1987 to 2018 with 95% confidence intervals for 2012 and 2018.

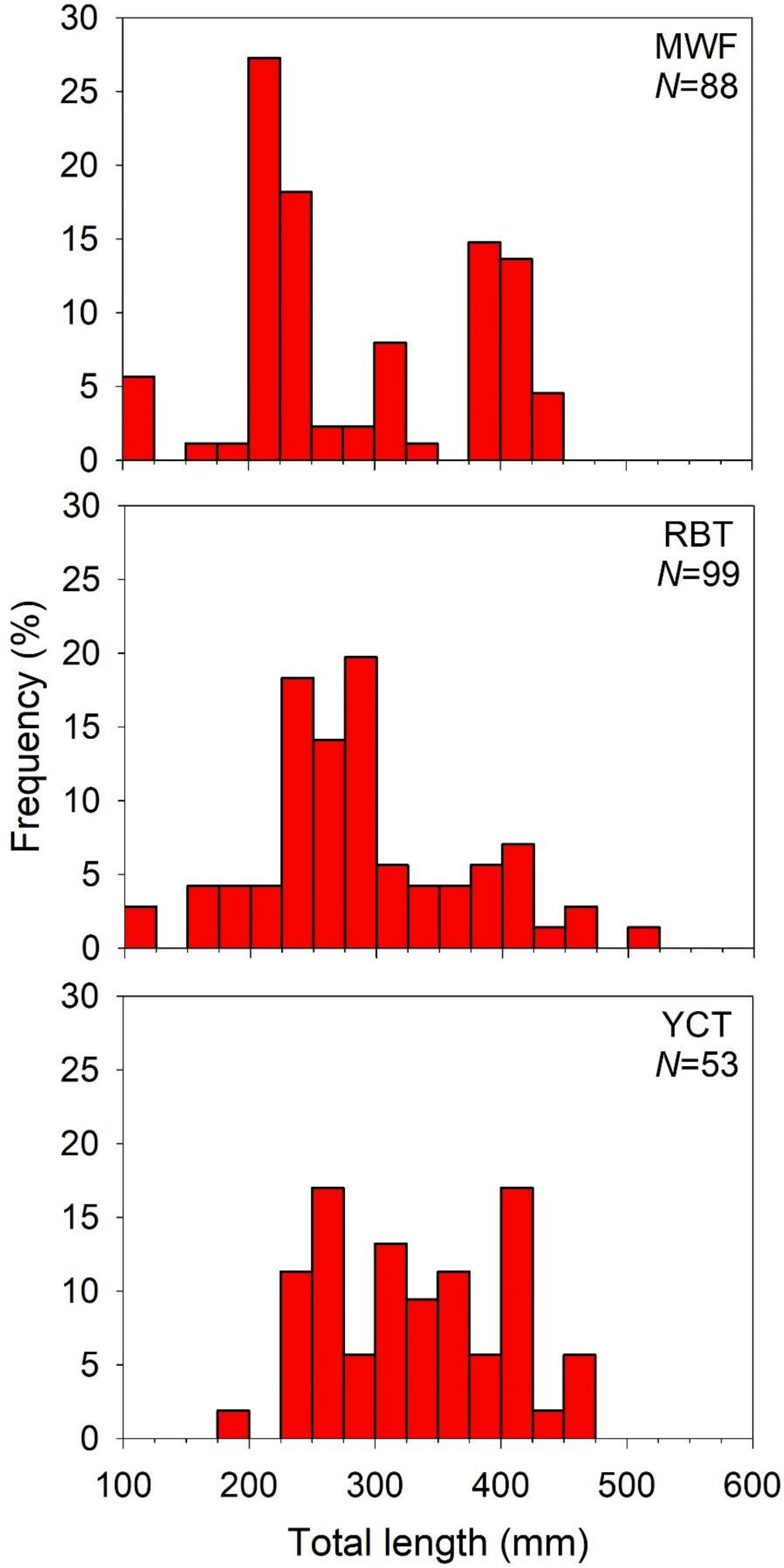

Figure 35. Length-frequency distribution of Mountain Whitefish (MWF), Rainbow Trout (RBT), and Yellowstone Cutthroat Trout (YCT) in the Bartlett Point reach of the Big Lost River, 2017.

HENRYS LAKE

ABSTRACT

Henrys Lake is one of the most popular recreational fisheries in Idaho, and is known to support a robust trout fishery. We used 50 gillnet nights of effort in the spring of 2018 to evaluate trout populations in Henrys Lake. The catch per unit effort (CPUE) for all trout species was 4.3 trout per net night (± 0.9; 95% CI), which was below the 25-year average of 12.2 and the management target of 11 trout per net night. Gill-net catch rates for Brook Trout *Salvelinus fontinalis* (1.7 ± 0.5), Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* (YCT; 1.5 ± 0.5), and hybrid trout (Rainbow Trout *Oncorhynchus mykiss* x Yellowstone Cutthroat Trout; 1.1 ± 0.3) were all below their long-term averages. Mean relative weight for all trout species (all sizes combined) were similar to previous years and ranged from 91 to 106. Utah Chub *Gila atraria* CPUE was slightly higher at 3.0 per net night than 2017. Stomach contents of 244 fingerling YCT were examined to assess diet composition one to four weeks post stocking. Diets were dominated by amphipods (~84%) while zooplankton (~3%) composed a small portion of the diet. We monitored dissolved oxygen levels under the ice to assess the possibility of a winterkill event from December 13th, 2017 through January 26th, 2018. Based on depletion estimates, we predicted dissolved oxygen would not reach critical levels (10 g/m^2), therefore we did not start aeration pumps. Parentage based tagging indicated a 1.6% wild YCT contribution to the lake in 2018.

Authors:

Jenn Vincent
Regional Fisheries Biologist

Jon Flinders
Regional Fisheries Biologist

Brett High
Regional Fisheries Manager

INTRODUCTION

Henrys Lake, located in eastern Idaho in the Greater Yellowstone Ecosystem, has provided a recreational trout fishery since the late 1800s (Van Kirk and Gamblin 2000). A dam was constructed on the outflow of the natural lake in 1924 to increase storage capacity for downstream irrigation. This dam increased total surface area to 2,630 ha with a mean depth of 4 m and inundated lower portions of tributary streams. The mouths of tributary streams historically provided spawning habitat for adfluvial Yellowstone Cutthroat Trout, prompting concerns for recruitment limitations. To mitigate for this potential loss of recruitment, the Idaho Department of Fish and Game (IDFG) acquired a private hatchery on the shores of Henrys Lake and began a fingerling trout stocking program that continues today (Garren et al. 2008). The lake supports a robust fishery for native Yellowstone Cutthroat Trout *Oncorhynchus clarkii bouvieri* (YCT), triploid hybrid trout (Rainbow Trout *O. mykiss* x Yellowstone Cutthroat Trout; HYB) and triploid Brook Trout *Salvelinus fontinalis* (BKT), with an average of approximately 132,000 hours of annual angling effort. Surveys of Idaho's anglers indicate Henrys Lake has been the most popular lentic fishery in the state (IDFG 2001). Since 1923, IDFG has stocked a total of over 90 million YCT, 11.3 million HYB, and 4.2 million BKT. Beginning in 1998, all HYB were sterilized prior to release to reduce the potential for hybridization with native YCT. Although hybridization was not a concern with BKT, only sterile fingerlings have been stocked since 1998 (with the exception of 50,000 fertile fish in 2003) to reduce the potential for naturally-reproducing BKT to compete with native salmonids.

Utah Chub (UTC) were first documented in the gillnet catch of 1993. By the early 2000s, UTC catch per unit effort began to increase and reached a high of 30.5 (median UTC per net night) in 2014. This population increase was coupled with a change in species catch composition from the dominant catch of YCT to UTC. Concerns on both direct and indirect negative interactions of UTC on YCT have been voiced by both the public and fisheries managers. As such, potential interactions between these two species will need to be studied.

Anglers view Henrys Lake as a quality fishery capable of producing large trout, and is currently managed as a trophy trout fishery (IDFG 2001). As early as the mid-1970s, 70% of interviewed anglers preferred the option of catching large fish even if it meant keeping fewer fish (Coon 1978). Since that time, management of Henrys Lake has emphasized restrictive harvest regulations consistent with providing a quality fishery as opposed to liberal harvest regulations that are more consistent with a yield fishery. In 1984, fisheries managers created specific, quantifiable objectives to measure angling success on Henrys Lake. Based on angler catch rate information and harvest data collected during creel surveys conducted between 1950 and 1984, managers thought it was possible to maintain angler catch rates of 0.7 trout per hour, with a size objective of 10% of harvested YCT exceeding 500 mm. These objectives remain in place today, although the size objective is now measured from gill net sampling as opposed to fish caught by anglers and measured during creel surveys (IDFG 2019). To evaluate these objectives, annual gill net monitoring occurs in May, immediately after ice off and prior to the fishing season, while creel surveys are conducted on a three- to five-year intervals.

STUDY SITE

Henrys Lake is located 1,973 m above sea level, between the Henrys Lake Mountains and the Centennial mountain range, approximately 29 km west of Yellowstone National Park. The lake is approximately 6.4-km long and 3.2-km wide, with a surface area of 2,630 ha. The outlet of

Henrys Lake joins Big Springs Creek to form the headwaters of the Henrys Fork Snake River (Figure 36).

OBJECTIVES

To obtain current information on the fish population, and to develop appropriate management recommendations to achieve management objectives stated in the State Fish Management Plan.

METHODS

Population Monitoring

As part of routine population monitoring, we set gill nets at six standardized locations in Henrys Lake in paired floating and sinking nets. Nets were set from May 9 – May 19, 2018 for a total of 50 net nights between all six sites (Figure 36; Appendix D). We alternated between floating and sinking gill nets at each site with gill nets measuring 46-m long by 2-m deep, with equal length panels of 2-, 2.5-, 3-, 4-, 5-, and 6-cm bar mesh. Nets were set at dusk and retrieved the following morning. We identified captured fish to species and recorded total lengths (TL; mm) and weights (g). Gill net catch per unit effort (CPUE) was calculated as mean fish per net night with 95% confidence intervals for each individual gill net. Due to the high variability and schooling behavior of Utah Chub, we cannot assume normal distribution and calculated CPUE as the median Utah Chub per net night.

We examined all YCT handled through the year for adipose fin clips as part of our evaluation of natural reproduction. Beginning in the 1980s, 10% of all stocked YCT have been marked with an adipose fin clip prior to stocking (Appendix E). To estimate contributions to the YCT population from natural reproduction, we calculated the ratio of marked to unmarked fish collected in our annual gill-net surveys and from trout captured ascending the fish ladder on Hatchery Creek. Since 10% of all stocked fish were marked with an adipose clip, ratios near 10% in the at-large population would be expected in the absence of additional, un-marked fish (natural reproduction). When the ratio of marked fish is less than 10%, we assumed that natural reproduction was contributing to the population. In 2017, the program shifted to using Parentage Based Tagging to gather information on hatchery vs. wild production which is described in detail below.

We removed the sagittal otoliths of all trout captured in gill nets for age and growth analysis. After removal, all otoliths were cleaned and stored in individually-labeled vials and analyzed as whole otoliths. Whole otoliths were immersed in water on a slide and the annuli were counted. Two trained readers independently assigned ages for each structure without reference to fish length. A total of 10 YCT otoliths were randomly subsampled and their ages were assessed per 20-mm size class. When less than 10 otoliths were present per size class, all otoliths were used to assign ages to fish. We determined ages for all BKT and HYB collected.

Images of otoliths were captured using the microscope interfaced with a desktop computer and whole otoliths. The von Bertalanffy growth model was used to fit length:

$$l_t = L_\infty(1 - e^{-K(t-t_0)})$$

where l_t is length at time t, L_∞ is the asymptotic length, K is a growth coefficient, and t_0 is a time coefficient at which length would theoretically be 0 (von Bertalanffy 1957). The model was fitted to length-at-age data by using the nonlinear model (NLIN) procedure in program R. We estimated instantaneous total mortality (Z) for each trout species using a weighted regression catch curve analysis (Maceina and Bettoli 1998). Age-1 trout were excluded from the analysis due to lack of recruitment to our gillnetting gear.

Relative weights (W_r) were calculated by dividing the actual weight of each fish (in grams) by a standard weight (W_s) for the same length for that species multiplied by 100 (Anderson and Neumann 1996). Relative weights were then averaged for each length class (< 200 mm, 200-299 mm, 300-399 mm, and fish > 399 mm). We used the formula, log W_s = -5.194 + 3.098 log TL (Anderson 1980) to calculate relative weights of HYB, log W_s = -5.189 + 3.099 log TL for Cutthroat Trout (Kruse and Hubert 1997) and log W_s = -5.186 + 3.103 log TL for BKT (Hyatt and Hubert 2001). For Utah Chub we used the formula log W_s = -4.984 + 3.049 log TL (Flinders, unpublished data).

We calculated proportional stock density (PSD) and relative stock density (RSD-400 and RSD-500) to describe the size structure of trout populations in Henrys Lake. We calculated PSD for YCT, HYB, and BKT using the following equation:

$$\text{PSD} = \frac{\text{number} \geq 300 \text{ mm}}{\text{number} \geq 200 \text{ mm}} \times 100$$

We calculated RSD-400 for YCT, HYB, and BKT using the following equation:

$$\text{RSD-400} = \frac{\text{number} \geq 400 \text{ mm}}{\text{number} \geq 200 \text{ mm}} \times 100$$

Criteria used for PSD and RSD-400 values for YCT, HYB, and BKT populations were based on past calculations and kept consistent for comparison purposes. We also calculated RSD-500, using the same equation as above, but used the number of fish greater than 500 mm as the numerator. This methodology (and size designation) is used on other regional waters to provide comparison between lakes and reservoirs throughout the Upper Snake Region.

Hybrid Evaluation

In order to assess the effect of paternal strain on HYB performance, we used fluorescent grit to mark two strains of HYB stocked into Henrys Lake as outlined by Flinders et al. 2016a. In 2015 and 2016, a total of 126,797 Gerrard and 209,088 Hayspur-strain HYB were marked with fluorescent grit for identification and stocked into Henrys Lake as fingerling trout. Trout collected in the gill nets (< 500 mm TL) were visually examined using a black light for the presence of the fluorescent mark to determine strain of HYB (chartreuse = Gerrard, and orange = Hayspur).

Parentage Based Tagging

Parentage Based Tagging (PBT) has been implemented since 2017 in conjunction with the YCT spawning operations each year. All YCT from the entire season spawn take were sampled. Genetic samples were stored on Whatman paper appropriately labeled by spawn date and lot number. Whatman paper was pre-labeled with seven horizontal sample locations on each plane. The first seven slot plane was identified as male with the next plane identified as female. These two horizontal planes were identified as Family 1. This was repeated vertically down the Whatman paper with the next two male/female planes identified as Family 2 and so forth. Genetic samples were obtained from all phenotypically-identified YCT and HYB encountered during our annual gill-net survey.

We captured fingerling YCT and HYB using nighttime shoreline boat electrofishing on May 21 and 22, 2018 to assess the wild contribution of YCT in the lake. We sampled fish near County, Hatchery, and State Park (Figure 36). When possible we collected fish in equal proportions from the three locations. Genetic samples were obtained from all phenotypically-identified YCT and HYB captured via an upper caudal fin clip and stored on pre-labeled Whatman paper.

Stocking Conditions

Prior to stocking in Henrys Lake, all HYB, YCT, and BKT fingerlings were measured on September 19, 2018 at Mackay Hatchery for total length to the nearest mm and weighed to the nearest hundredth of a gram. Additional YCT were measured in the same manner at the American Falls Hatchery on September 25, 2018. Fulton's condition factor (K_i) was estimated using the following equation:

$$K_i = \frac{W_i}{L_i^{\,3}} \times 100{,}000$$

where L_i and W_i are the observed length and weight for the *i*th fish (Neumann et al. 2012).

Water temperatures at the time of stockings in the lake were monitored via Hobo temperature loggers (Onset, USA) located at three sites (hatchery, county, and state park; Appendix D). At each site, three temperature loggers were placed throughout the water column (surface, middle, and bottom). Water temperatures were recorded at 15-minute intervals and then averaged for one day post stocking (fish stocked at ~2:00 PM each day) to determine water temperatures at and shortly after the time of stocking. Water temperatures were also recorded in the tanks during transportation of fingerlings to evaluate the temperature differences between the tanks and Henrys Lake.

Age-0 Diets and Growth

We collected recently stocked YCT (age-0) using night-time boat electrofishing along the shoreline in September and October 2018 to assess diet composition from one to four weeks post-stocking. We collected fish weekly after initial stocking for four weeks near County, Hatchery, and State Park. When possible, we collected fish in equal proportions from the three locations to obtain a spatially variable diet. All fish collected were weighed (to the nearest 0.01 g) and measured (TL; mm). We evaluated differences in predicted weights at a variety of lengths of BKT and YCT using lwCompPreds in the FSA package of program R, which determines if the parameters from a similar linear regression fit are statistically different between sampling intervals (R Core Development Team 2018). For diet analysis, stomachs were removed immediately after collection, stored in individually labeled containers, and preserved in containers with 95% EtOH. We determined dietary composition by manually removing, separating, and identifying prey. For each stomach, we identified individual prey items using a dissecting scope. We separated items by genus and then counted and weighed each genus to the nearest thousandth of a gram (i.e., 0.001 g). We also measured all prey to the nearest 0.1 mm with an ocular micrometer. Length-dry mass equations from the literature were used to estimate the mass (mg) of each macroinvertebrate (Benke et al. 1999; Dumont et al. 1975; Rogers et al. 1976; Weiland and Hayward 1997). Identified prey items were summarized as percent weight of the total contents and percent of the total contents by number. Prey taxa that were consumed infrequently or in low proportions were combined into the other invertebrate categories of Coleoptera, Ephemeroptera, Hemiptera, Hymenoptera, Simuliidae, and Tricoptera.

We estimated diets of YCT using mean percent by weight:

$$MW_i = \frac{1}{P}\sum_{j=1}^{P}\left(\frac{W_{ij}}{\sum_{i=1}^{Q} W_{ij}}\right),$$

where MW_i is the mean percent by weight, P = number of fish with food in their stomachs, Q = number of food categories, and W_{ij} = weight of prey type i in fish j. Only stomachs containing prey items were utilized for calculations and analyses.

Stable Isotope Analysis

Brook Trout, YCT, HYB, and Utah Chub were collected from six gill-net nights of effort on October 17 and October 25, 2018 to assess the diet composition of each species through stable isotope analysis (SIA). One gill net was set at each of the six standardized netting locations used for population monitoring and randomly assigned each location as a floating or sinking net set. Additional Utah Chub were collected by boat electrofishing on October 24, 2018 near the County Park. A small portion (about 1 cm^3) of white muscle tissue without skin was dissected below the dorsal fin and above the lateral line from each fish, placed in a labeled bag, and immediately placed on ice.

Carbon (^{13}C) and nitrogen (^{15}N) stable isotope ratios were performed using a Finnigan Delta Plus continuous-flow isotope ratio mass spectrometer and elemental analyzer (Thermo Fisher Scientific Inc., Waltham, MA, U.S.A) at the University of Arkansas, Stable Isotope Laboratory. Samples were weighed to 0.25-0.35 mg in individual 3.5-mm x 5-mm tin capsules. Stable isotope ratios were given using the standard delta notation ($\delta^{13}C$; $\delta^{15}N$) per mil (‰) according to the following formula:

$$\delta I = [(R_{\text{sample}}/R_{\text{standard}}) - 1] \times 10^3,$$

where I is the isotope of interest (^{13}C or ^{15}N) and R is the $^{13}C/^{12}C$ or $^{15}N/^{14}N$ ratio in the sample and the standard. Standards employed were Vienna Pee Dee Belemnite for $^{13}C/^{12}C$ and atmospheric N_2 for $^{15}N/^{14}N$. Analytical precision (i.e., standard deviation) calculated from internal standards was 0.04‰ for ^{13}C and 0.06‰ for ^{15}N. Stable isotope analyses was completed on a total of 9 BKT, 12 YCT, 9 HYB, and 20 UTC. We stratified fish by 10-mm size classes and randomly selected samples within each stratum in an effort to evaluate SIA across a broad size range.

To evaluate niche overlap of trout and UTC we used population metrics originally developed by Layman et al. (2007) and recently improved by Jackson et al. (2011). We used the stable isotope Bayesian ellipses in the SIBER package (Parnell et al. 2010) in program R (R Core Team 2012). We calculated standard ellipse areas (SEA_c), with a small sample size correction (subscript 'c'), for each fish species. A SEA_c is the bivariate measure of the distribution of individuals in trophic space. The estimated ellipse represents approximately 40% of the isotopic distribution of the individuals and represents the core dietary niche and typical resource use (Jackson et al. 2011, 2012).

Water Quality

Winter dissolved oxygen

Winter dissolved oxygen concentrations (mg/L), snow depth (m), ice thickness (m), and water temperatures (°C) were measured at five established sampling sites (Pittsburg Creek, Outlet, County Boat Dock, Wild Rose, and Hatchery; Appendix D) on Henrys Lake between December 13th, 2017 and January 28th, 2018 (Figure 36). Holes were drilled in the ice with an electric ice auger prior to sampling. A YSI model Pro-20 oxygen probe was used to collect dissolved oxygen and temperature readings at the bottom of the ice and at subsequent one-meter intervals until the bottom of the lake was encountered. Dissolved oxygen mass was calculated from the dissolved oxygen probe's mg/L readings and converted to total mass in g/m^2. This was a direct conversion from mg/L to g/m^2 (i.e., 1,000 L = 1 m^2). The individual dissolved oxygen readings at each site were then summed to determine the total available oxygen within that sample site. To calculate this value, we used the following formula;

[Average (bottom of ice + 1m)] + [Sum (readings from 2 m to lake bottom)] = Total O_2 mass

The total mass of dissolved oxygen at each sample site was then expressed in g/m^2 (Barica and Mathias 1979). Data were then transformed using the natural logarithm (ln*)* for regression analysis. We used linear regression to estimate when oxygen levels would deplete to the critical threshold for fish survival (10.0 g/m^2).

Dissolved oxygen profiles were recorded each year to develop a dissolved oxygen depletion model used to predict the likelihood of the Henrys Lake environment reaching the critical threshold for fish survival. Historically, the critical threshold at Henrys Lake has been 10 g/m^2. The likelihood of reaching the critical dissolved oxygen threshold prior to April 1, the projected recharge date, is one factor which was used to decide whether to deploy aeration at Hatchery Creek's mouth.

Open-water water temperature

We monitored yearly water temperatures via Hobo (Onset, USA) temperature loggers located at three sites (Hatchery, County, and State park). Temperature loggers were deployed shortly after ice-off on May 15th and retrieved on October 25th, 2018. At each site three temperature loggers were placed throughout the water column (surface, middle, and bottom). Water temperatures were recorded at 15-minute intervals.

RESULTS

Population Monitoring

We collected 1,489 fish in 50 net nights in May 2018, with our standard spring gill-net survey. Gill-net catch rates (CPUE) for all trout species combined was 4.3 fish per net night (± 0.9; 95% CI; Figure 37). Catch composition was 85.5% UTC, 5.6% BKT, 5.1% YCT, and 3.7% HYB. Mean (± 95% CI) trout CPUEs were highest for BKT at 1.7 fish per net night (± 0.5), followed by YCT at 1.5 (± 0.5), and HYB at 1.1 fish per net night (± 0.3). Mean CPUEs for each species were lower than their 25-year average of 6.4 (YCT), 3.5 (HYB), and 2.3 (BKT) per net night, respectively (Figure 38). Hybrid trout total lengths ranged from 160 to 759 mm with a mean of 443 mm (± 35.1). Yellowstone Cutthroat Trout total lengths ranged from 160 to 608 mm with a mean of 386 mm (± 24.0). Brook Trout total lengths ranged from 148 to 549 mm with a mean of 218 mm (± 10.6; Figure 39). Of the 76 YCT collected in gill nets, we found 2 (3%) marked with adipose fin clips (Table 16).

The mean CPUE of Utah Chub was 25.5 fish per net night (± 95% CI 13.1; Figure 40). This gill-net catch rate was higher than in 2017 (20.5 ± 11.8), but was not statistically different based on overlapping CIs. Utah Chub total lengths ranged from 105 to 450 mm with a mean of 235 mm (± 3.5; Figure 41).

Proportional stock density was highest for HYB (96) followed by YCT (88), and BKT (5). Relative stock density (RSD-400) was highest for HYB (58) followed by YCT (41) and BKT (2; Table 17). Mean relative weight for all sizes combined was 106 for HYB (± 2.5), 96 for YCT (± 2.1) and 91 (± 1.7 BKT; Table 18) and W_r of YCT age-2 and age-3 were 99 to 96, respectively (Figure 42). Mean relative weight for UTC (all sizes combined) was 100 (± 0.44) and ranged between 98 and 101 for size classes (100–199 mm, 200–299 mm, 300–399 mm; Figure 43). Overall W_r of UTC increased from 2017. Whereas, YCT mean relative weight remained similar to 2017 (Figure 44).

Ages

We estimated the ages of 74 BKT, 69 YCT, and 53 HYB. Ages ranged from age-1 to age-6 for BKT, age-1 to 7 for YCT, and age-1 to 7 for HYB. We did not collect any age-4 and age-5 BKT, as a result we were unable to estimate their mean length at age using non-linear regression. Mean length for age-2 fish was slightly higher for YCT at 324 mm TL (range 215 to 334 mm) compared to HYB at 318 mm TL (range 299 to 333 mm) (Table 18; Figure 45). Yellowstone Cutthroat Trout grew from a starting age of t_0 = 0.04 years (-0.45 to 0.52) toward their asymptotic length of L_∞ = 619 mm (538 to 700 mm) at an instantaneous rate of K = 0.38/year (0.21 to 0.54; Figure 46). Hybrid trout exhibited poor fit with the non-linear regression model due the lack of asymptotic growth with age. Estimated HYB starting age was t_0 = -1.10 years (-2.43 to 0.23) toward their asymptotic length of L_∞ = 2,425 mm (-2,744 to 7,595 mm) at an instantaneous rate of K = 0.05/year (-0.008 to 0.17; Figure 47). Catch curve analysis of HYB and YCT mortality estimates from age-2 to 5 were 31% and 36%, respectively.

Hybrid Evaluation

We captured 7 HYB with chartreuse (Gerrard) and 6 HYB with orange (Hayspur) fluorescent marks in 2018 (Table 19). The overall average size (± 95% CI) and range of HYB collected was 400 mm (± 62.7; range 334-506 mm) for the Gerrard strain and 409 mm (± 105.1; range 320-528 mm) for the Hayspur strain. Age-2 HYB of the Hayspur strain exhibited a slightly larger total length than the Gerrard strain (*t*-test, $t = 3.64$, $p = 0.03$). Age-3 HYB between Gerrard and Hayspur strains were not different between total length (*t*-test, $t = 1.59$, $p = 0.09$), although sample size was too low (Table 19) to determine significance.

Parentage Based Tagging

A total of 1,610 YCT were genotyped for the 2018 Henrys Lake YCT spawn. All YCT and HYB fingerling genetic samples collected from our spring electrofishing survey were analyzed for parentage. Of the 227 samples collected, 33 samples were genetically identified as HYB, 188 as YCT, and 3 (1.3%) failed to genotype. For the YCT genotyped samples, 185 YCT were assigned to BY2017 while 3 YCT failed to assign to the baseline. This indicates the wild contribution of YCT for 2018 was 1.6%. A total of 158 sampled were phenotypically identified as Cutthroat Trout with 145 samples genetically identified as Cutthroat Trout and 13 as HYB. A total of 63 samples were phenotypically identified as HYB with 20 samples genetically identified as HYB and 43 as Cutthroat Trout. Field staff were 91.8% accurate in phenotypically identifying juvenile YCT and 31.7% accurate for HYB.

Age-0 Diets and Growth

Mean length for age-0 fish prior to stocking was slightly higher for YCT at 82 mm (95% CI ± 0.9) compared to HYB at 79 mm (95% CI, ± 1.8; Table 20). Based on length frequency, BKT ranged from 76 to 150 mm across the three weeks after stocking (Figure 48). Length frequency of YCT ranged from 50 to 140 mm across the four weeks after stocking (Figure 49). Mean weight decreased two weeks after stocking and then increased to a similar weight at the time of stocking by week three for both BKT (Figure 50) and YCT (Figure 51). We examined 97, 102, 75, and 56 YCT stomachs in week 1, week 2, week 3, and week 4, following stocking in Henrys Lake, respectively. Diets of the fingerling YCT were dominated by amphipods (~84%; Figure 52), while zooplankton (~3%) only comprised a small portion of the diet across the four weeks.

Stable Isotope Analysis

Utah Chub and BKT were the most enriched with the carbon isotopic signature ($\delta^{13}C$). In contrast, HYB and YCT were the most depleted in carbon isotopes (Table 21; Figure 53). As HYB increased in length their carbon isotopic signature increased up to 600 mm in length. The two HYB trout over 600 mm in length exhibited lower carbon signatures than any other sized HYB. In general, all trout less than 300 mm utilized similar nitrogen sources. Overall, as BKT and HYB trout increased in total length, they were less enriched with the nitrogen isotopic signature ($\delta^{15}N$). A linear regression indicated the nitrogen isotopic signature of UTC decreased significantly with increasing fish size ($p = 0.0001$; Table 22; Figure 54).

Hybrid trout exhibited the widest ($SEA_c = 1.94$) and BKT the narrowest dietary niches ($SEA_c = 0.56$; Table 23). Yellowstone Cutthroat Trout and UTC displayed moderate dietary niche widths of 1.24 and 1.13, respectively. A significant dietary niche overlap in the SEA_c between ellipses existed (< 0.60) for HYB and YCT of 0.79 (Table 24; Figure 55). Dietary niches did slightly overlap between UTC and each individual trout species, but was not significant.

Water Quality

<u>Winter dissolved oxygen</u>

Total dissolved oxygen diminished from 50.7 to 20.0 g/m^2 at the Pittsburgh Creek site, from 42.7 to 17.9 g/m^2 at the Wild Rose site, from 21.1 to 17.0 at the County dock site, from 21.2 to 12.1 g/m^2 at the Hatchery site, and from 23.1 to 13.1 g/m^2 at the Outlet site (Table 25). Depletion estimates indicated dissolved oxygen would remain below the level of concern throughout the winter and no aeration was initiated (Figure 56).

<u>Open-water temperatures</u>

The highest observed water temperatures occurred on July 15th, 21st, and 31st near the surface at all three sites, County (23.7 °C), Hatchery (22.3 °C), and State (22.8 °C), respectively (Figure 57). Temperature differences at each site between the strata (surface, middle, bottom) averaged 1.4 °C, 0.5 °C, and 0.4 °C difference at County, Hatchery, and State, respectively, from May to October.

<u>DISCUSSION</u>

This year marks the fourth year of declining total trout CPUE, and for which CPUE was below the management goal of 11 trout per net night (IDFG 2013). The total trout CPUE and each trout species CPUE were also below the 25-year average. Although we observed a decline in trout abundance, there was no significant change in trout condition. Relative weights for all size classes and species of trout were at, or near, 100 indicating these fish have reached their growth potential. As such, any potential limiting factors such as changes in forage base or abiotic factors (e.g., temperature, dissolved oxygen, or water-level fluctuations), are likely not causing substantial adverse effects on the population. The high observed PSD values further indicate trout are in good condition since high PSD values indicate low population densities of faster growing fish and are associated with high relative weight values (Anderson 1980). A large component of the BKT captured (96%) were less than 300 mm in length and identified as age-1, age-2, and age-3 BKT. Brook Trout were stocked in lower numbers in 2014 and 2015 (83,000 and 71,000, respectively) when compared to the last two years (202,000 and 105,000, respectively). This may have attributed to the current paucity of age-4 and age-5 BKT in the population.

We have limited inferences on UTC densities due to high variability in gill-net catch (i.e. high variance). Utah Chub are currently the most common species caught in our gill net surveys most likely due to their high reproductive potential. Average W_r for all size classes for UTC increased from 2017 and was 100 indicating these fish are in good condition. We examined feeding niches of BKT, HYB, YCT and UTC using stable isotope analysis. There is evidence of competition between UTC and trout for both food resources and space in many lakes and reservoirs. Potential competition between young UTC and Cutthroat Trout for prey resources has been documented in Scofield Reservoir, Utah (Johnson and Belk 2006). However, this does not seem to be the case in Henrys Lake, as little overlap in dietary niches were observed between UTC and all trout species in both 2014 (Flinders et al. 2016b) and 2018. Hybrid trout had the narrowest trophic niche width suggesting a more specialized diet while BKT appear to be more opportunistic feeders relying on a diversity of prey as seen in their wide trophic niche. As expected, there was significant overlap observed in the dietary niches of HYB and YCT, due to the genetic similarities between HYB and YCT.

As UTC age and grow in the lake, they begin to move to a higher trophic position, as shown with their increasing $\delta^{15}N$ signatures with total length. These relationships were also observed in 2014 (Flinders et al. 2016b). Direct competition for food resources between UTC and trout may not appear to be of immediate concern in Henrys Lake, but interspecific competition for space and other abiotic factors may become more problematic as UTC age and increase in trophic overlap with trout. Furthermore, in the event that the UTC population significantly increases, or there is a significant change in the abundance and/or species composition of the forage base, competition for food resources may be a cause for concern. As such, the interaction between UTC and trout should be monitored periodically to ensure predator-prey dynamics are stable and the fishery continues to produce trophy-sized trout.

Hatchery trout are particularly vulnerable to mortality directly following stocking. Recently stocked fish are susceptible to piscivorous predators, may not be able to quickly adapt to a lake environment, and lack the instinctive behavior needed to compete for preferred prey items. In 2014, we found *Daphnia sp.*, followed by scuds, were the mostly commonly consumed prey items for YCT from August through October. Zooplankton were also highly abundant in September and October 2018 (unpublished data). We expected zooplankton to be the most common prey for stocked fingerling YCT to be zooplankton, but were surprised that the diet of YCT fingerlings was dominated by amphipods. Scuds contain a slightly higher caloric content (~3,300 J/g), when compared to other benthic invertebrates (~3,000 J/g), and represent a more energetically profitable prey (Flinders 2012). Once hatchery fish began consuming scuds, their relative weights began to increase. This indicates hatchery YCT have adequate time to adapt to the lake environment and may be less stressed prior to winter. The increase in body condition should lead to increased overwinter survival of these fish.

To maintain Henrys Lake as a trophy trout fishery, we conducted a study evaluating two strains of male Rainbow Trout to fertilize YCT eggs and produce the Henrys Lake HYB. Our goal was to guide future stocking efforts on which strain of HYB is best suited for Henrys Lake by comparing egg eye-up rates, fry survival, and the post-stock growth and survival of these trout. The stocked Hayspur-strain HYB were found to be longer in total length at age-2, while there was no difference between the strains at age-3, although due to low sample sizes it is hard to draw significant conclusions. Due to the positive cost-benefit of using trout procured and raised at our IDFG Hayspur hatchery, coupled with the increased growth rate observed with this HYB strain, all HYB trout stocked into Henrys Lake since 2016 have been fertilized by the Hayspur strain. This year, both Hayspur (6) and Gerrard (7) strain HYBs were captured, and the condition of the Hayspur strain was higher across all ages compared to the Gerrard strain. After three years, it is expected that some of these fish have been lost to either natural mortality or harvest. This year's capture of healthy Hayspur HYBs shows the potential for our HYB to persist in the lake and provide long-term angling opportunities for the public.

Wild YCT contribution to the lake was very low, an estimated 1.6% of the 2018 population using PBT assignments. The use of PBT at Henrys Lake began with SY2017. Prior to 2017, 10% of the stocked hatchery YCT in Henrys Lake were marked by an adipose fin clip to evaluate natural recruitment. There is some error associated with mass marking techniques including miss clips (partial or no clip), improper identification of miss clips, and the low rate at which fish are clipped relative to the number stocked. Only 10% of approximately one million fingerling YCT stocked into Henrys Lake each year were marked with an adipose clip. From 2009 to 2013, the average ratio of adipose clipped fish in our gill-net surveys was 5%, indicating an increase in wild YCT contribution. This increase in wild contribution was likely due to the habitat restoration projects which have occurred during the last two decades on the major tributaries of Henrys Lake (High et al. 2014). These projects have included fish passage improvements, irrigation canal screening and riparian fencing. Parentage Based Tagging is a cost effective method which allows for mass marking of all YCT stocked into Henrys Lake and removes any error associated with ratio estimates. This coupled with our continued gill-net and juvenile trout surveys will allow us to answer a seemingly unlimited number of management questions which can help inform our stocking methods (e.g. size, time of year), habitat restoration projects, population analysis, and spawning operations.

MANAGEMENT RECOMMENDATIONS

1. Continue annual gill-net survey using 50 net nights of effort.
2. Collect otolith samples from all trout species captured during gill-net surveys to compare total lengths of age classes through time.
3. Continue to monitor Utah Chub densities and evaluate potential impacts of increased densities of Utah Chub on trout.
4. Periodically conduct diet and stable isotope analysis of trout and Utah Chubs to evaluate dietary and isotopic overlap between these species.
5. Utilize PBT to evaluate the percentage of wild production in Henrys Lake.
6. Plan on conducting the next full season creel survey in 2019.
7. Continue to monitor winter dissolved oxygen levels to determine when using the aeration system is required.
8. Fund and implement habitat work as outlined by the Henrys Lake Technical Team.

Table 16. Adipose fin clip data from Yellowstone Cutthroat Trout (YCT) stocked in Henrys Lake. Annually, from 1996 to 2016, 10% of stocked YCT received an adipose fin clip. Fish returning to the Hatchery ladder and fish captured in annual gill-net surveys are examined for fin clips.

Year	No. Clipped	No. checked at Hatchery	No. detected	Percent clipped	No. checked in gill nets	No. detected	Percent clipped	Overall percent clipped
1996	100,290	--	--	--	--	--	--	--
1997	123,690	178	5	3%	--	--	--	3%
1998	104,740	--	--	--	--	--	--	--
1999	124,920	160	20	13%	--	--	--	13%
2000	100,000	14	1	7%	--	--	--	7%
2001	99,110	116	22	19%	--	--	--	19%
2002	110,740	38	7	18%	--	--	--	18%
2003	163,389	106	37	35%	273	47	17%	22%
2004	92,100	--	--	--	323	28	8%	9%
2005	85,124	2,138	629	29%	508[a]	55	11%	26%
2006	100,000	2,455	944	39%	269[a]	20	8%	35%
2007	139,400	--	--	--	770	70	9%	9%
2008	125,451	4,890	629	13%	100	10	10%	13%
2009	138,253	4,184	150	4%	91	9	10%	4%
2010	132,563	4,253	90	2%	505	31	6%	3%
2011	112,744	3,037	137	5%	1,097[b]	72	7%	5%
2012	75,890	2,880	215	7%	500	52	10%	8%
2013	75,600	3,360	268	8%	478	47	10%	8%
2014	72,900	6,226	651	10%	626[b]	60	10%	10%
2015	95,500	5,211	627	12%	254	24	9%	12%
2016	100,750	4,689	548	12%	238	27	11%	12%
2017[c]	--	--	--	--	149	12	8%	--
2018[c]	--	--	--	--	76	2	3%	--

[a] Includes fish from gill-net samples and creel survey.
[b] Includes fish from annual spring gill-net monitoring and fish collected in monthly stomach sample gill netting.
[c] No fish were clipped due to the parentage based tagging implemented in 2017.

Table 17. Stock density indices (PSD, RSD-400, and RSD-500) and relative weights (W_r) with 95% confidence intervals in parenthesis for all trout species collected with gill nets in Henrys Lake, 2018.

	Brook Trout	hybrid trout	Yellowstone Cutthroat Trout
PSD	5	96	88
RSD-400	2	50	41
RSD-500	2	37	21
W_r			
<200 mm	86 (1.5)	95 (--)	88 (2.7)
200–299 mm	92 (1.9)	112 (--)	92 (9.0)
300–399 mm	109 (138.5)	104 (4.3)	100 (2.4)
>399 mm	85 (--)	108 (3.2)	94 (3.7)

Table 18. Summary statistics of total length (TL; mm), weight (WT; g), and relative weights (W_r) for Brook Trout (BKT), hybrid trout (HYB), Yellowstone Cutthroat Trout (YCT), and Utah Chub (UTC) collected in the spring gillnetting at Henrys Lake, 2018.

Summary statistic	BKT TL (mm)	BKT WT (g)	BKT W_r	HYB TL (mm)	HYB WT (g)	HYB W_r	YCT TL (mm)	YCT WT (g)	YCT W_r	UTC TL (mm)	UTC WT (g)	UTC W_r
Mean	218	132	91	443	1,404	106	386	793	96	235	216	100
Confidence Level (95.0%)	10.6	42.9	1.7	35.1	354.1	2.5	24.0	139.3	2.1	3.5	8.6	0.4
Median	215	104.5	89	396	790	105	351.5	504	96	229	168	99
Minimum	148	34	77	160	41	88	160	38	78	105	20	76
Maximum	549	1,748	130	759	5,684	129	608	2,646	119	450	715	127
Count	84	84	82	55	55	53	76	76	72	1,273	1,267	1,244

Table 19. Mean length at age data based on otoliths of Brook Trout (BKT), hybrid trout (HYB) and Yellowstone Cutthroat Trout (YCT) caught from gill nets in Henrys Lake, 2018. Mean length-at-ages were estimated using non-linear regression.

Species	Summary statistic	Age 1	2	3	4	5	6	7
BKT	Mean TL (mm)	208	227	271	--	--	594	--
	Lower 95% CI	148	196	226	--	--	--	--
	Upper 95% CI	262	250	315	--	--	--	--
	No. Analyzed	61	10	2	--	--	1	--
HYB	Mean TL (mm)	219	318	412	502	587	669	746
	Lower 95% CI	173	299	400	490	570	638	691
	Upper 95% CI	242	333	426	519	604	690	777
	No. Analyzed	1	17	14	13	5	3	2
YCT	Mean TL (mm)	185	324	419	484	528	558	579
	Lower 95% CI	151	315	407	472	513	535	549
	Upper 95% CI	213	335	431	496	543	583	614
	No. Analyzed	4	40	7	14	7	3	1

Table 20. Mean total length (TL; mm), weight (WT; g), and relative weight (W_r) by year, strain, and age of hybrid trout collected in the spring gillnetting at Henrys Lake, 2016-2018, that exhibited fluorescent marks.

				Mean (±95% CI)			Range		
Year	Strain	Age	N	TL (mm)	WT (g)	W_r	TL (mm)	WT (g)	W_r
2016	Hayspur	1	5	191 (± 39.8)	68 (± 39.4)	87 (± 10.6)	152-227	37-102	80-101
2017	Gerrard	1	1	274	221	97	--	--	--
		2	8	343 (± 27.8)	444 (± 110.4)	95 (± 6.7)	275-376	207-621	82-107
	Hayspur	1	2	--	--	--	160-239	38-136	88-91
		2	20	379 (± 13.8)	679 (± 71.5)	108 (± 4.1)	327-429	386-913	91-123
2018	Gerrard	2	2	--	--	--	334-336	426-444	91-105
		3	4	404 (± 87.1)	801 (± 631.8)	99 (± 11.6)	348-479	432-1,434	90-106
		4	1	506	1493	98	--	--	--
	Hayspur	2	2	--	--	--	361-365	717-1,281	105-129
		3	2	--	--	--	320-335	440-472	111-119
		4	2	--	--	--	535-538	1,877-2,016	104-109

Table 21. Summary statistics by year of total length (TL; mm), weight (WT; g), and condition (K) for fingerling hybrid trout (HYB) for both strains (Gerrard and Hayspur) and Yellowstone Cutthroat Trout (YCT) sampled at the Mackay Fish Hatchery prior to stocking at Henrys Lake.

		HYB (*Gerrard*)			HYB (*Hayspur*)			YCT		
Year	Summary statistic	TL (mm)	WT (g)	K	TL (mm)	WT (g)	K	TL (mm)	WT (g)	K
2015	Mean	85	5.15	0.80	85	5.93	0.92	--	--	--
	Confidence Level (95.0%)	2.5	0.55	0.04	2.5	0.54	0.03	--	--	--
	Median	87	5.20	0.80	86	5.85	0.92	--	--	--
	Minimum	65	1.60	0.58	65	3.10	0.74	--	--	--
	Maximum	107	10.80	1.52	110	11.60	1.14	--	--	--
	Count	47	47	47	47	46	46	--	--	--
2016	Mean	91	6.5	0.80	88	5.77	0.81	--	--	--
	Confidence Level (95.0%)	3.2	0.92	0.04	2.8	0.63	0.03	--	--	--
	Median	92	5.78	0.79	88	5.45	0.81	--	--	--
	Minimum	65	2.01	0.78	66	2.34	0.58	--	--	--
	Maximum	120	23.84	0.60	107	11.00	1.02	--	--	--
	Count	52	52	52	54	54	54	--	--	--
2017	Mean	84	5.48	0.89	79	5.46	1.07	82	5.47	0.98
	Confidence Level (95.0%)	1.6	0.34	0.02	1.8	0.34	0.02	0.9	0.19	0.01
	Median	85	5.39	0.90	78	4.99	1.08	81.5	5.25	0.98
	Minimum	64	2.09	0.38	52	1.32	0.84	56	0.86	0.49
	Maximum	100	10.49	1.09	102	10.51	1.42	103	11.40	1.49
	Count	100	100	100	100	100	100	330	330	330
2018	Mean	--	--	--	75	4.21	0.96	79	4.77	0.92
	Confidence Level (95.0%)	--	--	--	1.5	0.27	0.02	1.1	0.19	0.01
	Median	--	--	--	76	4.23	0.97	80	4.72	0.91
	Minimum	--	--	--	50	1.24	0.69	52	1.33	0.59
	Maximum	--	--	--	96	8.80	1.29	105	10.48	1.40
	Count	--	--	--	120	120	120	280	280	280

Table 22. Sample size (n), δ^{13}C and δ^{15}N (mean ± SD), total length (mean ± SD; minimum and maximum), and standard ellipse area corrected for small sample size (SEA_c) of Brook Trout (BKT), hybrid trout (HYB), Yellowstone Cutthroat Trout (YCT), and Utah Chub (UTC) collected in Henrys Lake, 2018.

Species	n	δ^{13}C (‰)	δ^{15}N (‰)	Total length (mm)	SEA_c
BKT	7	-24.18 ± 0.37	9.69 ± 0.43	384 ± 91.2 (287-541)	0.56
HYB	10	-25.60 ± 0.48	9.67 ± 0.43	415 ± 99.1 (285-672)	1.94
YCT	11	-25.06 ± 0.71	9.52 ± 0.23	392 ± 79.4 (241-580)	1.24
UTC	17	-24.2 ± 0.21	9.41 ± 0.26	242 ± 35.4 (136-355)	1.13

Table 23. Linear regression results for stable isotope analysis (SIA) of δ^{13}C and δ^{15}N by total length for Brook Trout (BKT), hybrid trout (HYB), Yellowstone Cutthroat Trout (YCT), and Utah Chub (UTC) in Henrys Lake, 2018.

	δ^{13}C				δ^{15}N			
Species	R^2	df	F	P	R^2	df	F	P
BKT	0.06	1, 6	0.32	0.60	0.41	1, 6	3.51	0.12
HYB	0.11	1, 9	0.95	0.36	0.24	1, 9	2.56	0.15
YCT	0.04	1, 10	0.38	0.55	0.06	1, 10	0.53	0.48
UTC	0.09	1, 16	1.55	0.23	0.52	1, 16	16.2	0.001

Table 24. Comparison of SIBER overlap fraction index for Brook Trout (BKT), hybrid trout (HYB), Utah Chub (UTC), and Yellowstone Cutthroat Trout (YCT) in Henrys Lake, 2018. Bolded values indicate a significant diet overlap (>0.60) for SIBER index.

Species		SIBER
BKT	HYB	0.00
BKT	YCT	0.24
HYB	YCT	0.79
UTC	BKT	0.47
UTC	HYB	0.04
UTC	YCT	0.34

Table 25. Dissolved oxygen (DO; mg/l) levels recorded in Henrys Lake during winter monitoring 2017-2018.

Location	Date	DO Ice bottom	DO 1 meter	DO 2 meters	DO 3 meters	DO 4 meters	DO 5 meters	Total g/m^2
Pittsburgh Creek	Dec. 13, 2017	11.8	11.6	11.5	11.1	4.9	--	50.7
	Dec. 21, 2017	11.9	11.0	10.9	10.4	8.0	3.2	44.0
	Jan. 3, 2018	12.2	11.2	10.1	7.4	7.4	0.9	37.5
	Jan. 10, 2018	11.4	9.9	7.5	5.9	4.6	0.5	29.1
	Jan. 18, 2018	11.1	9.0	6.6	4.2	1.6	0.3	22.8
	Jan. 26, 2018	10.3	8.0	5.5	4	1.1	0.2	20.0
County Ramp	Dec. 13, 2017	11.8	12.7	8.4	0.4	--	--	21.1
	Dec. 21, 2017	11.3	10.7	10.9	4.2	--	--	26.1
	Jan. 3, 2018	10.7	9.5	7.5	2.4	--	--	20.0
	Jan. 10, 2018	10.8	8.6	6.5	1.4	--	--	17.6
	Jan. 18, 2018	10.7	8.3	5.0	0.8	--	--	15.3
	Jan. 26, 2018	10.0	7.3	4.0	3.9	0.4	--	17.0
Wild Rose	Dec. 13, 2017	11.7	11.0	10.8	10.3	7.3	2.9	42.7
	Dec. 21, 2017	12.3	11.9	10.6	9.5	4.1	--	36.3
	Jan. 3, 2018	12.0	10.5	8.1	6.8	0.6	--	26.8
	Jan. 10, 2018	10.9	9.5	7.7	5.5	0.6	--	24.0
	Jan. 18, 2018	10.7	9.8	8.1	4.7	0.3	--	23.3
	Jan. 26, 2018	9.3	7.9	6.5	2.6	0.2	--	17.9
Hatchery	Dec. 13, 2017	12.4	11.4	11.1	6.6	3.5	--	21.2
	Dec. 21, 2017	11.8	10.0	8.0	5.5	1.6	--	26.0
	Jan. 3, 2018	13.9	9.2	6.5	2.2	--	--	18.9
	Jan. 10, 2018	11.7	7.5	6.6	0.7	--	--	16.9
	Jan. 18, 2018	10.9	6.0	4.8	0.7	--	--	14.0
	Jan. 26, 2018	10.0	6.0	3.8	0.3	--	--	12.1
Outlet	Dec. 21, 2017	11.8	11.2	8.6	3.0	--	--	23.1
	Jan. 3, 2018	12.0	8.8	7.1	1.4	--	--	18.9
	Jan. 10, 2018	10.7	8.1	6.5	3.1	--	--	19.0
	Jan. 18, 2018	10.2	8.0	5.3	--	--	--	14.4
	Jan. 26, 2018	9.5	7.3	4.7	--	--	--	13.1

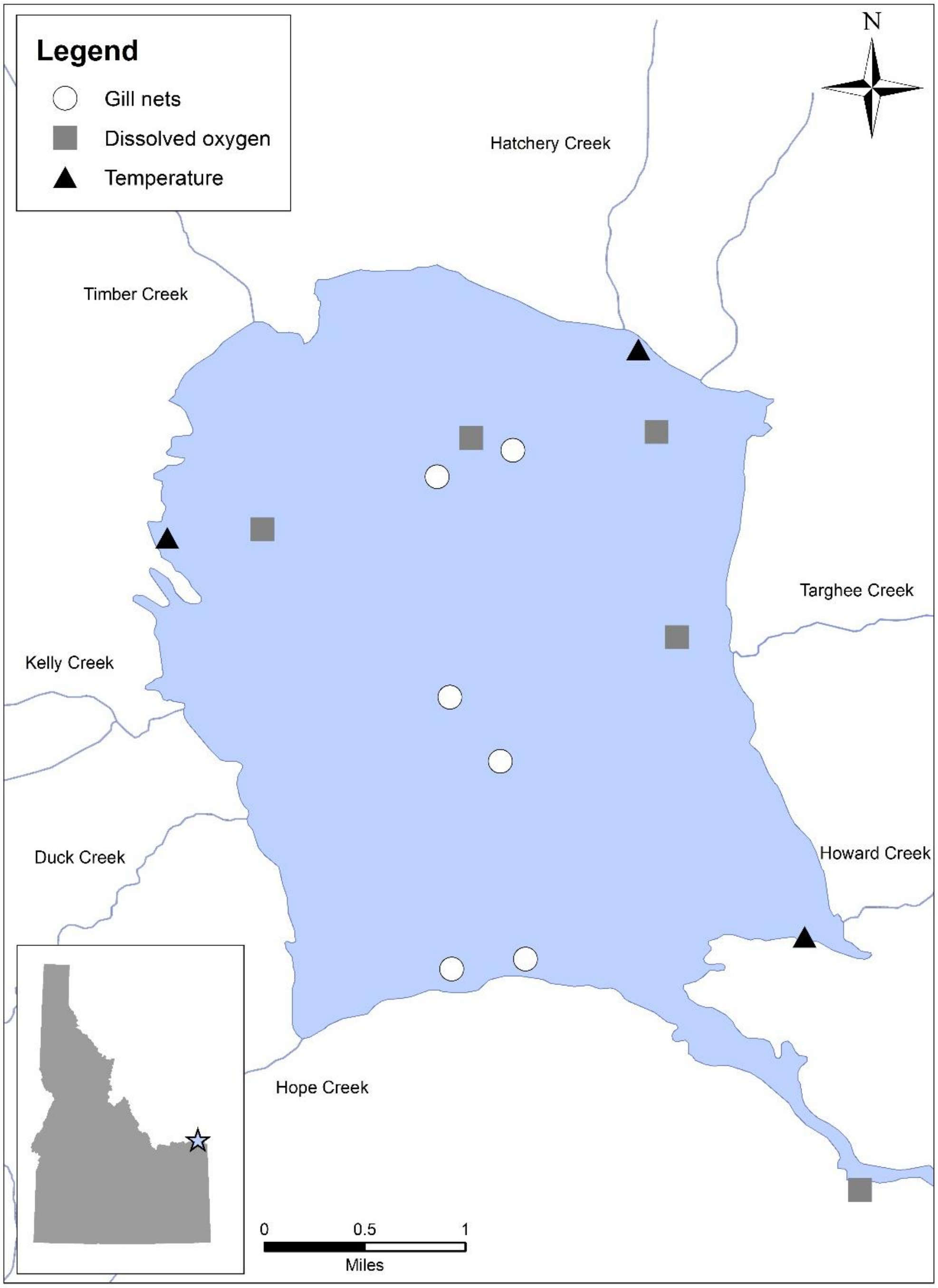

Figure 36. Locations of gill net, winter dissolved oxygen, and temperature monitoring sites in Henrys Lake, Idaho, 2018.

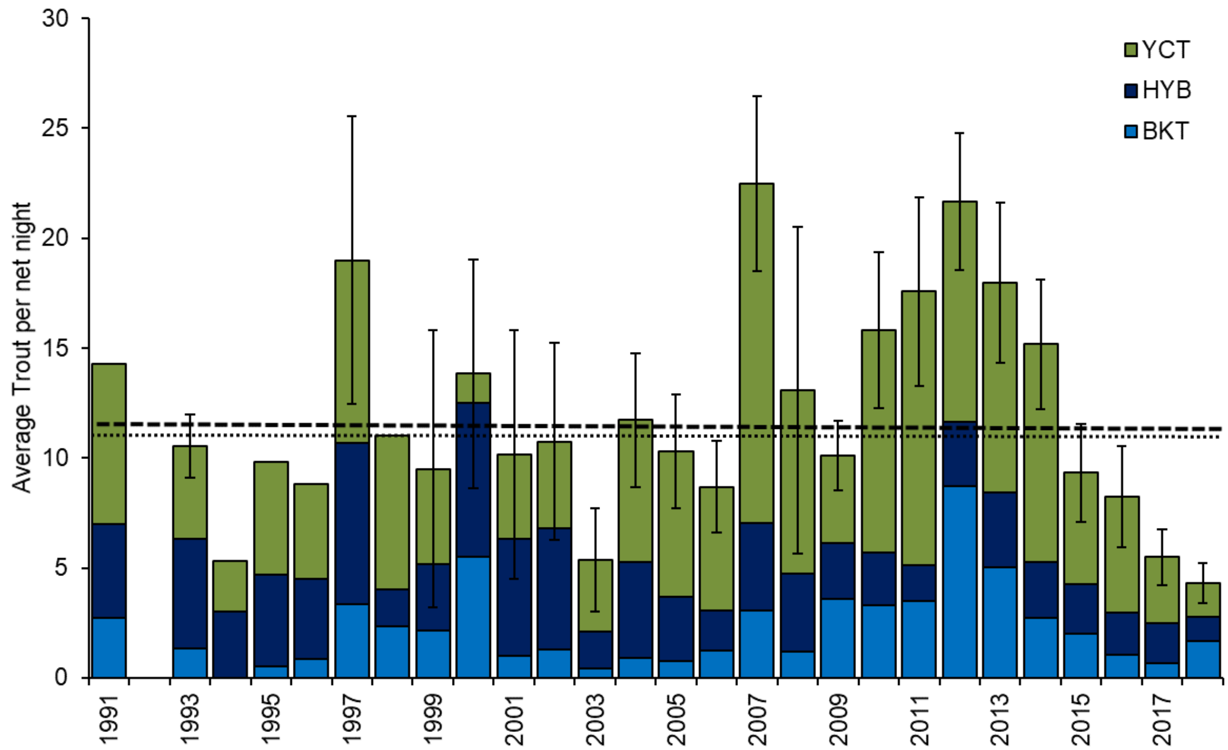

Figure 37. Catch per unit effort (CPUE) of trout per net night for Brook Trout (BKT), hybrid trout (HYB), and Yellowstone Cutthroat Trout (YCT) in Henrys Lake between 1991 and 2018. Error bars represent 95% confidence intervals. Lines represent the average gill net CPUE from years 1991 to 2017 (dashed line) and the management target of 11 trout per net night (dotted line).

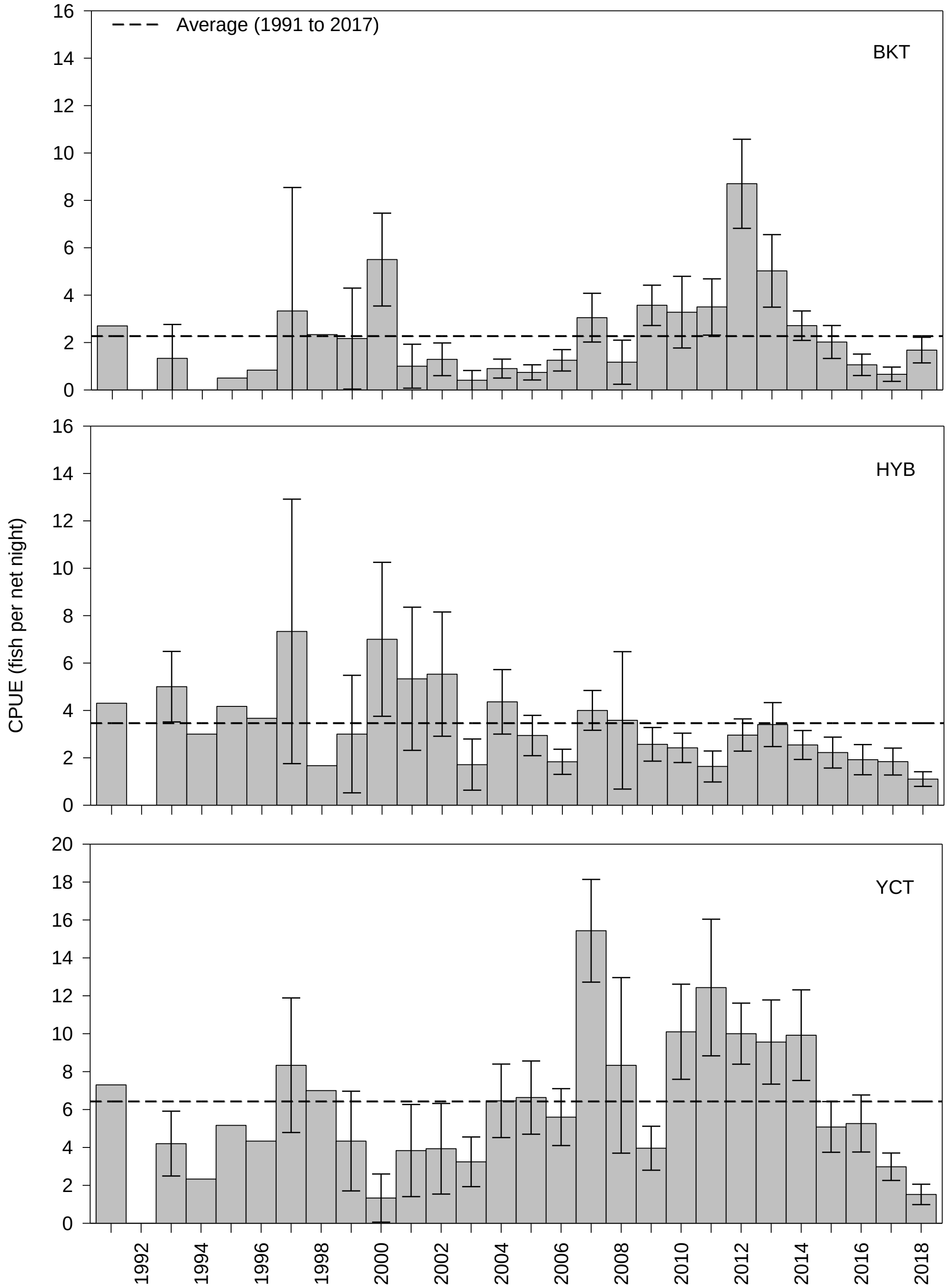

Figure 38. Catch per unit effort (CPUE) of fish per net night for Brook Trout (BKT), hybrid trout (HYB), and Yellowstone Cutthroat Trout (YCT) in Henrys Lake between 1991 and 2018. Error bars represent 95% confidence intervals. The dashed line represents the mean gill net CPUE from 1991 to 2017.

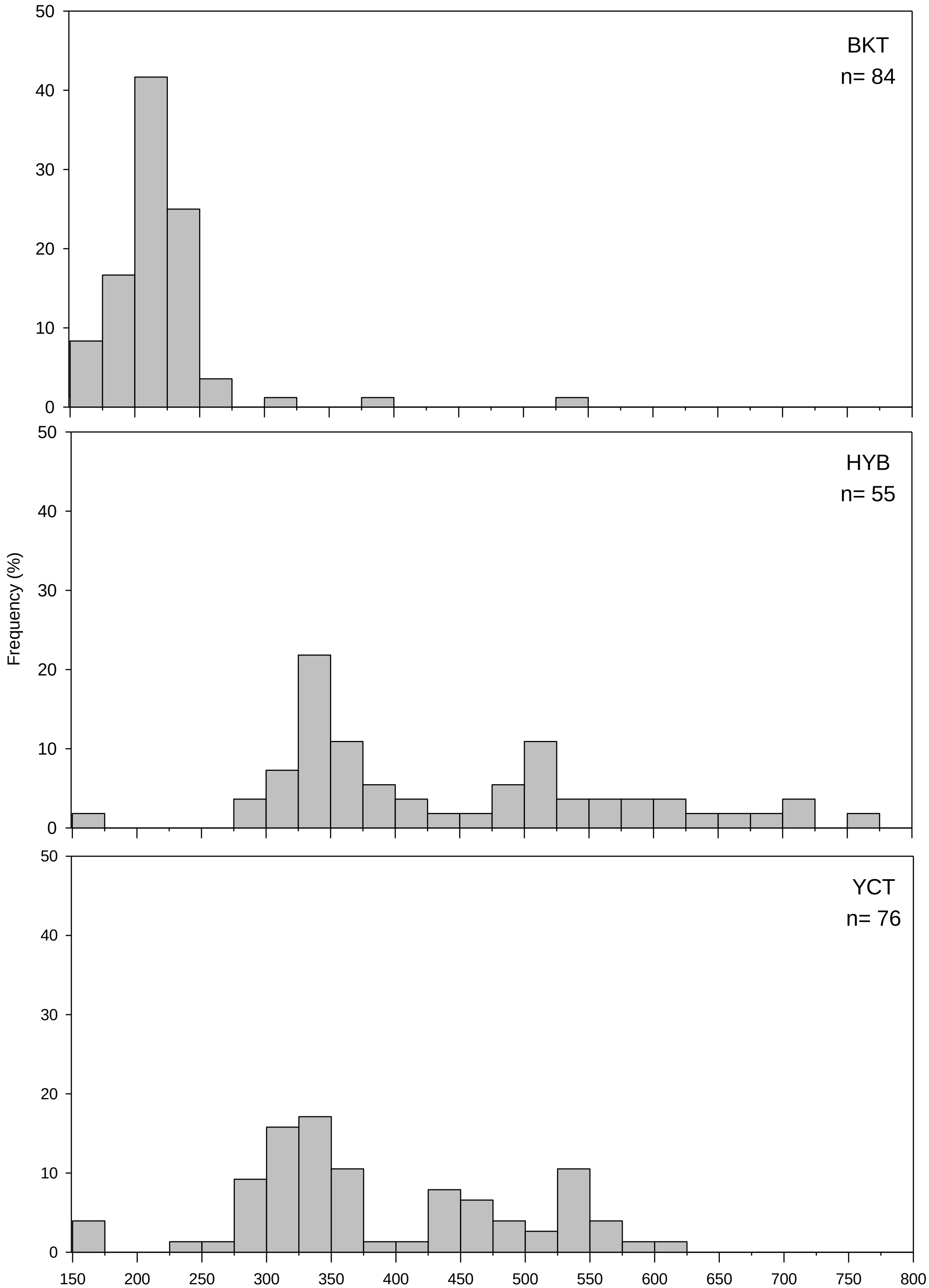

Figure 39. Brook Trout (BKT), hybrid trout (HYB) and Yellowstone Cutthroat Trout (YCT) length frequency (%) distribution from gill nets set in Henrys Lake, 2018.

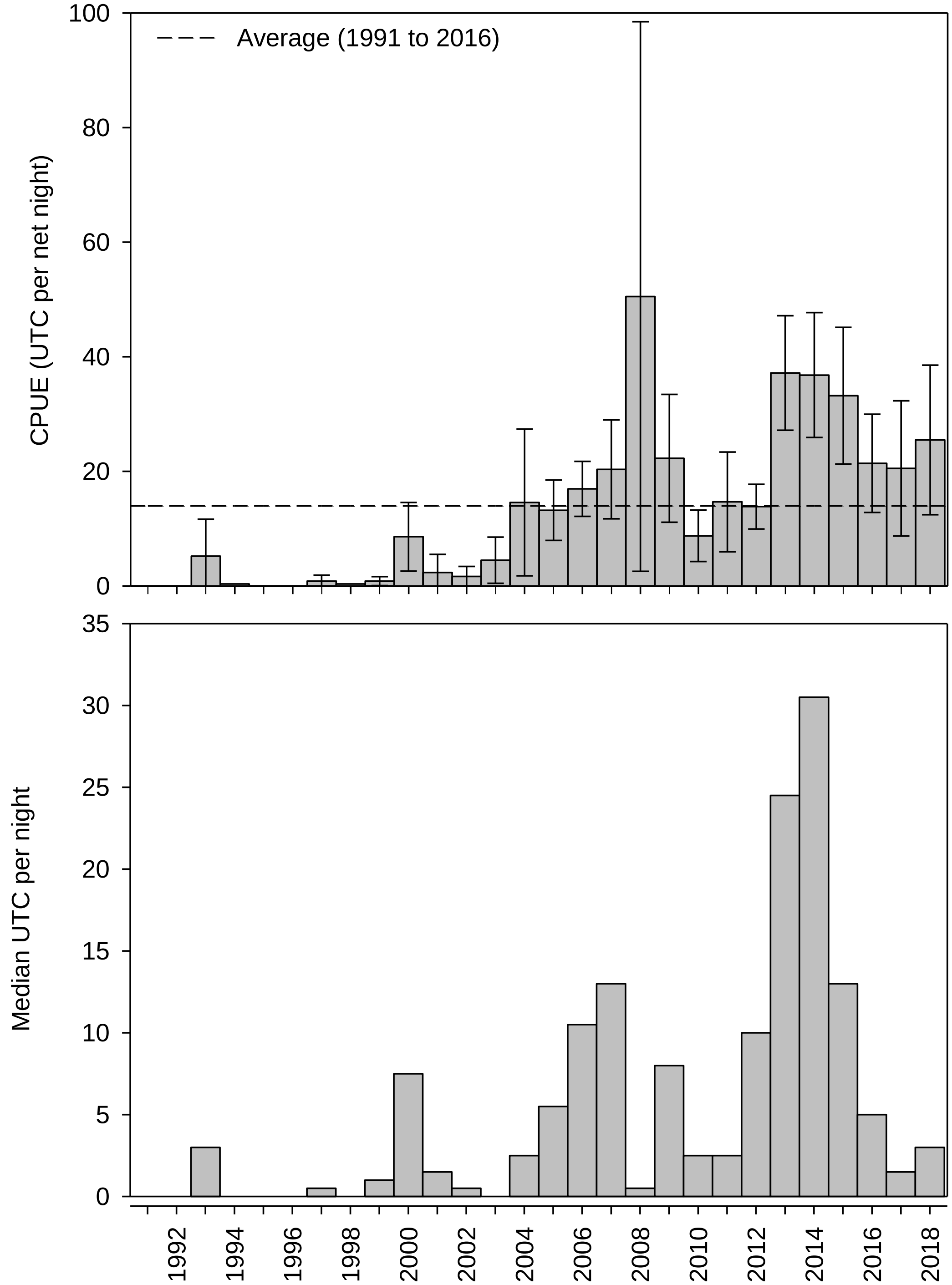

Figure 40. Mean catch per unit effort (CPUE) and median fish per net night for Utah Chub in Henrys Lake between 1991 and 2018. For the CPUE graph, error bars represent 95% confidence intervals and the dashed line represents the mean gill net CPUE from 1991 to 2017.

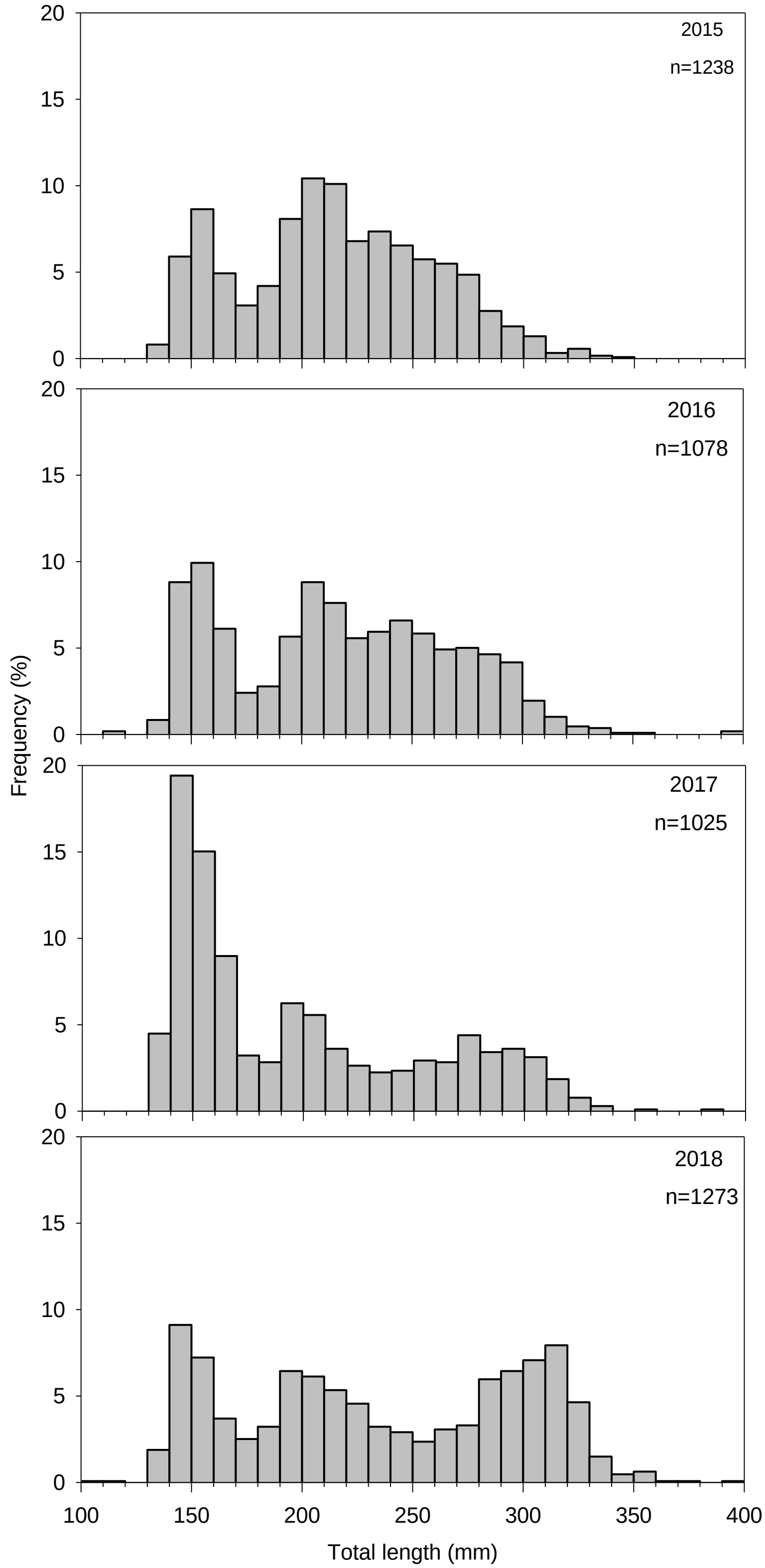

Figure 41. Utah Chub length-frequency distribution from gill nets set in Henrys Lake, 2015-2018.

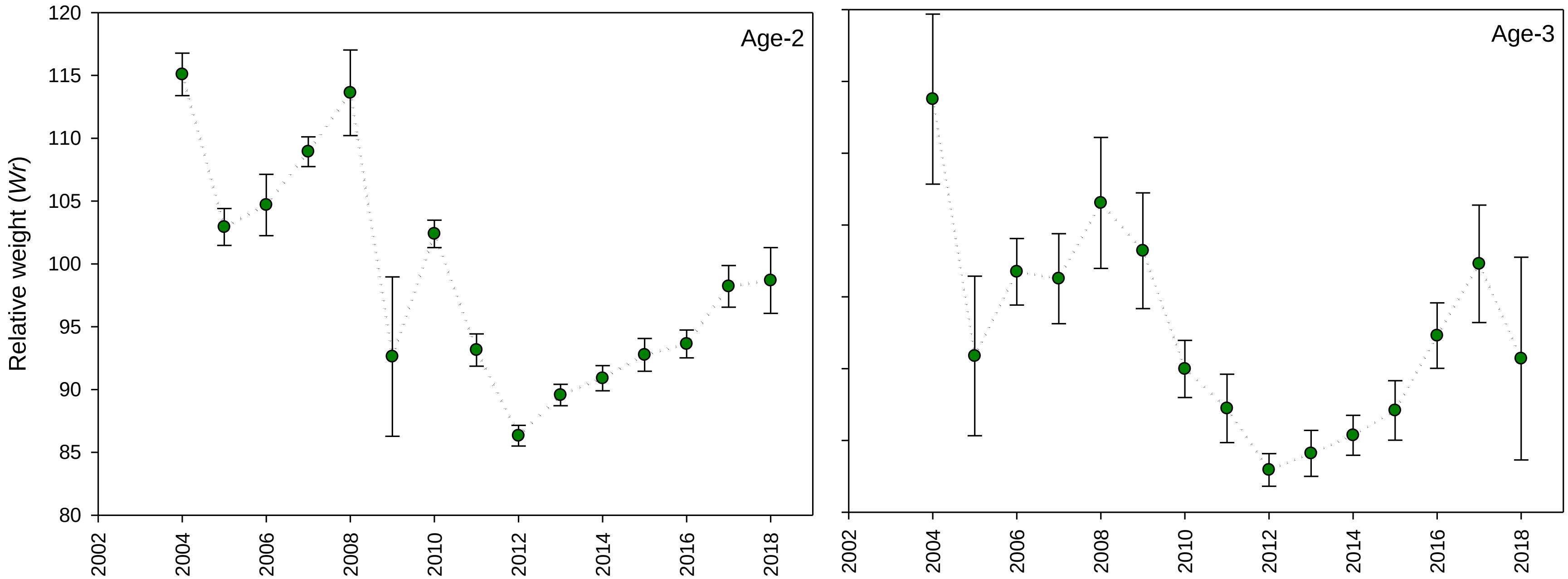

Figure 42. Relative weights (W_r) for age-2 and age-3 Yellowstone Cutthroat Trout from spring gill nets in Henrys Lake 2004-2018. Error bars represent 95% confidence intervals.

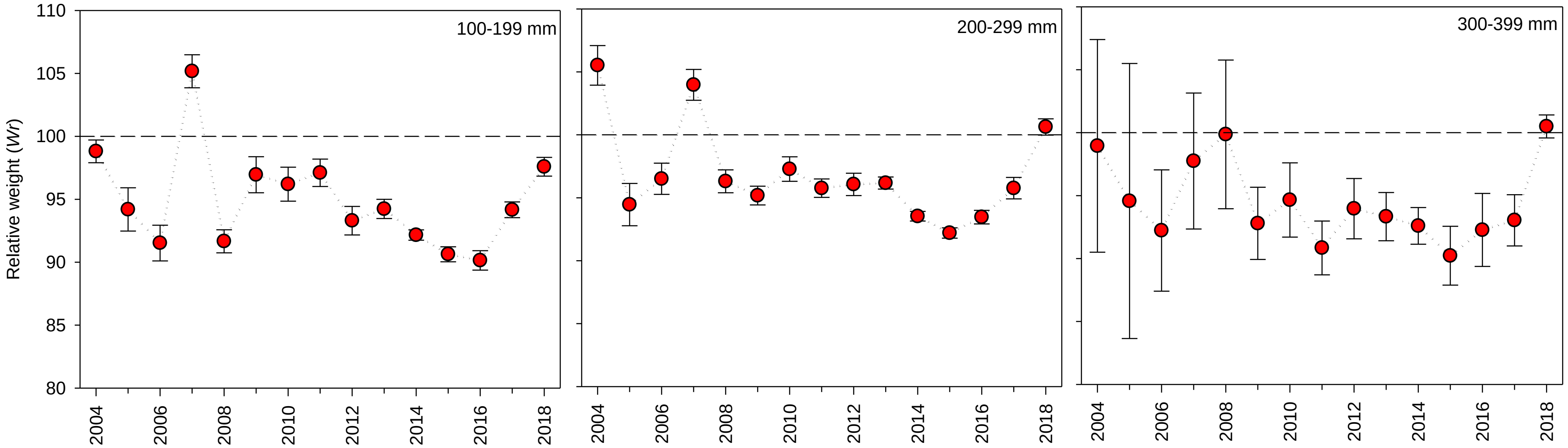

Figure 43. Relative weights (W_r) for three size classes (100–199 mm, 200–299 mm, 300–399 mm) of Utah Chub from spring gill nets in Henrys Lake 2004-2018. Error bars represent 95% confidence intervals.

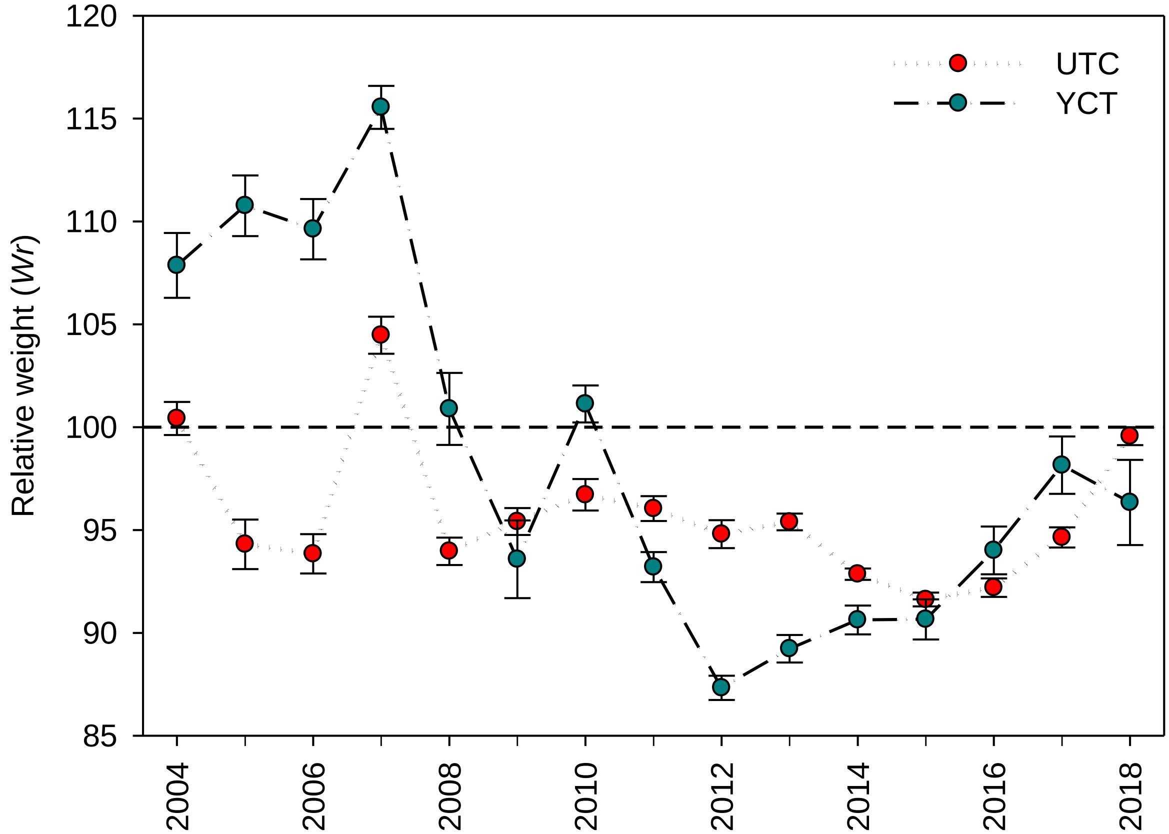

Figure 44. Relative weights (W_r) for all Yellowstone Cutthroat Trout (YCT) and Utah Chub (UTC) collected from spring gill nets in Henrys Lake 2004-2018. Error bars represent 95% confidence intervals.

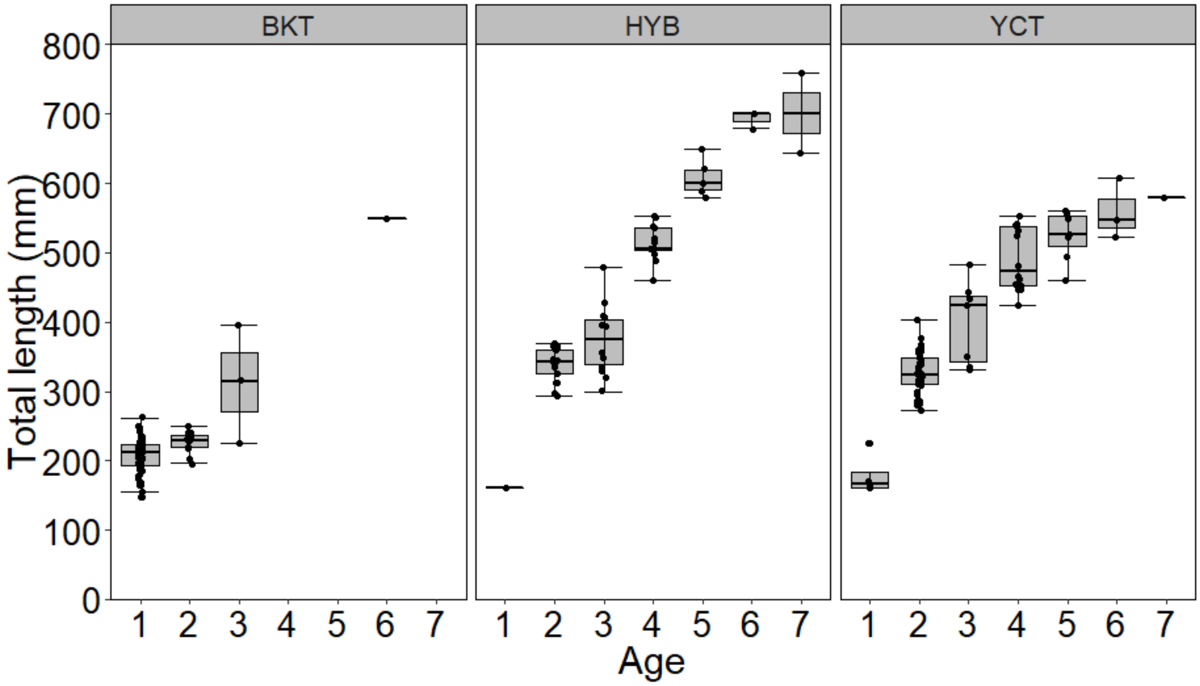

Figure 45. Box plot of mean length-at-age for Brook Trout (BKT), hybrid trout (HYB), and Yellowstone Cutthroat Trout (YCT) from spring gill nets in Henrys Lake, 2018. The bottom and top of the box indicate the first (Q1) and third (Q3) quartiles, and middle line in the box represents the median.

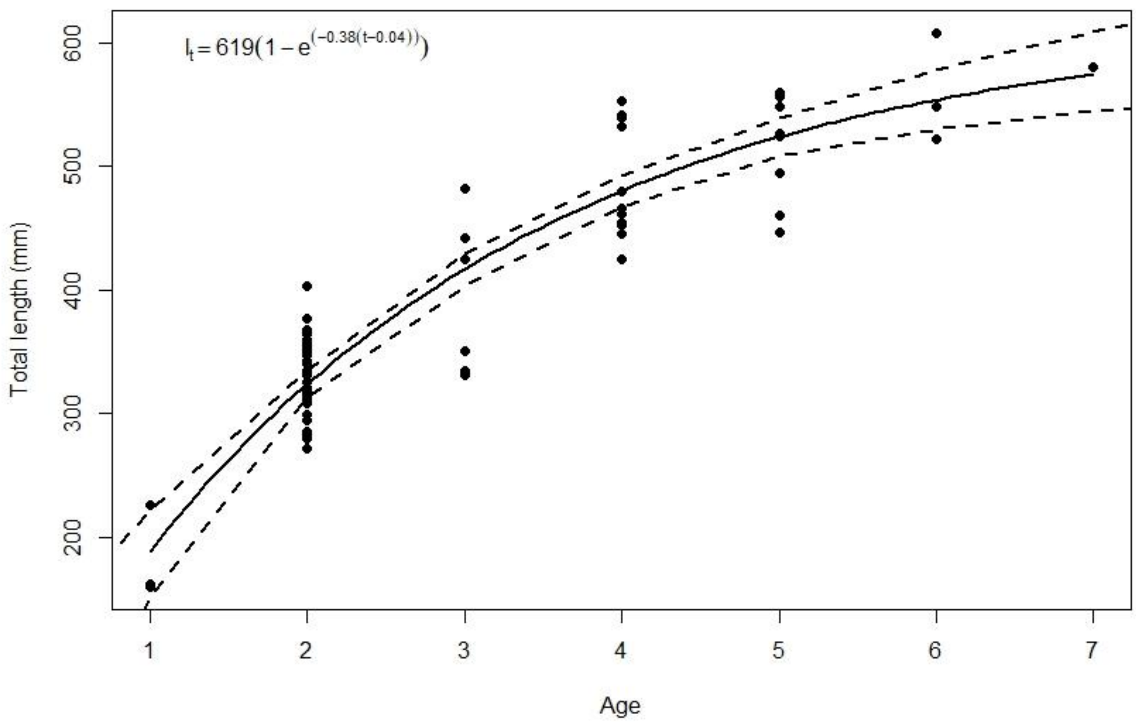

Figure 46. Von Bertalanffy growth model with 95% confidence intervals (dashed lines) for Yellowstone Cutthroat Trout aged from spring gill nets in Henrys Lake, 2018.

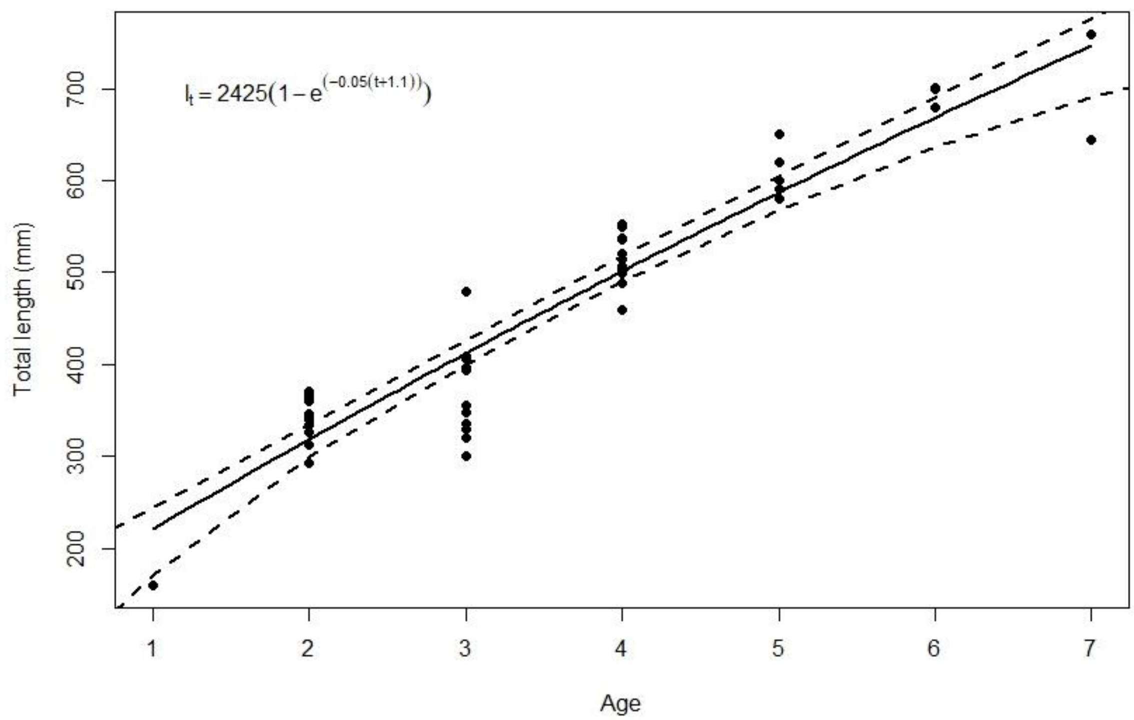

Figure 47. Von Bertalanffy growth model with 95% confidence intervals (dashed lines) for hybrid trout aged from spring gill nets in Henrys Lake, 2018.

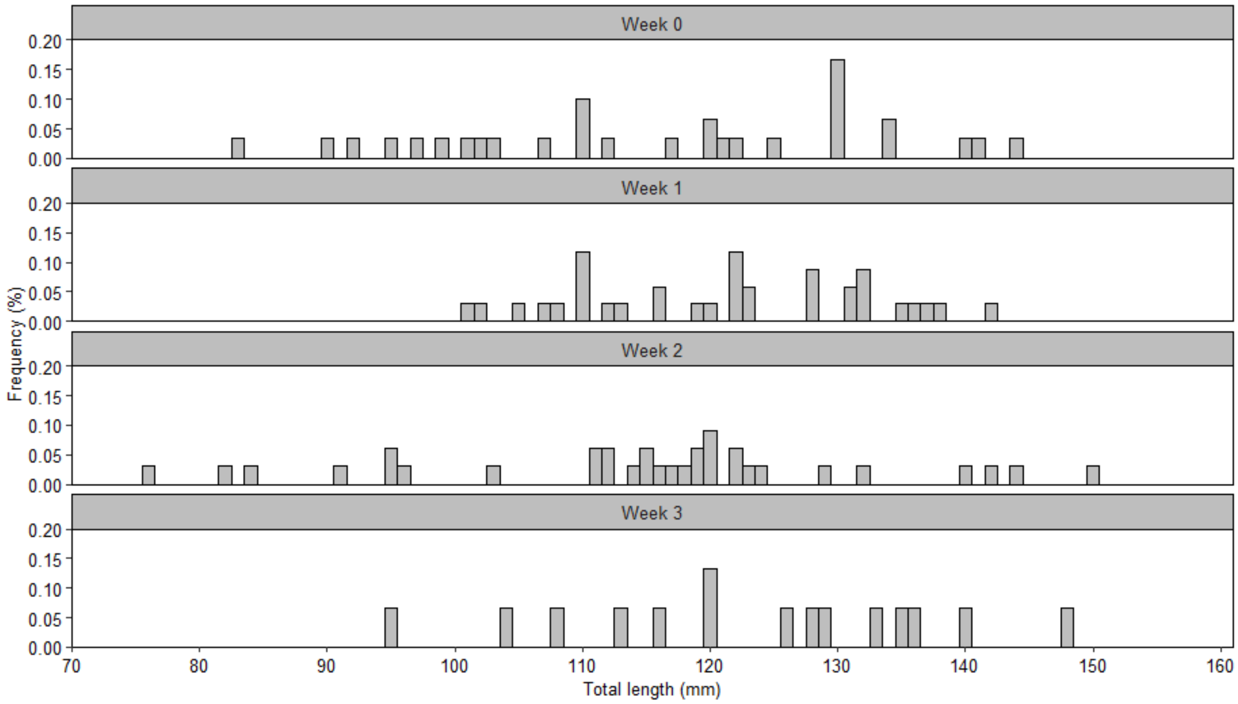

Figure 48. Brook Trout length-frequency distribution prior to stocking (Week 0) and collected from fall shoreline electrofishing surveys 1 to 3 weeks after stocking in Henrys Lake, 2018.

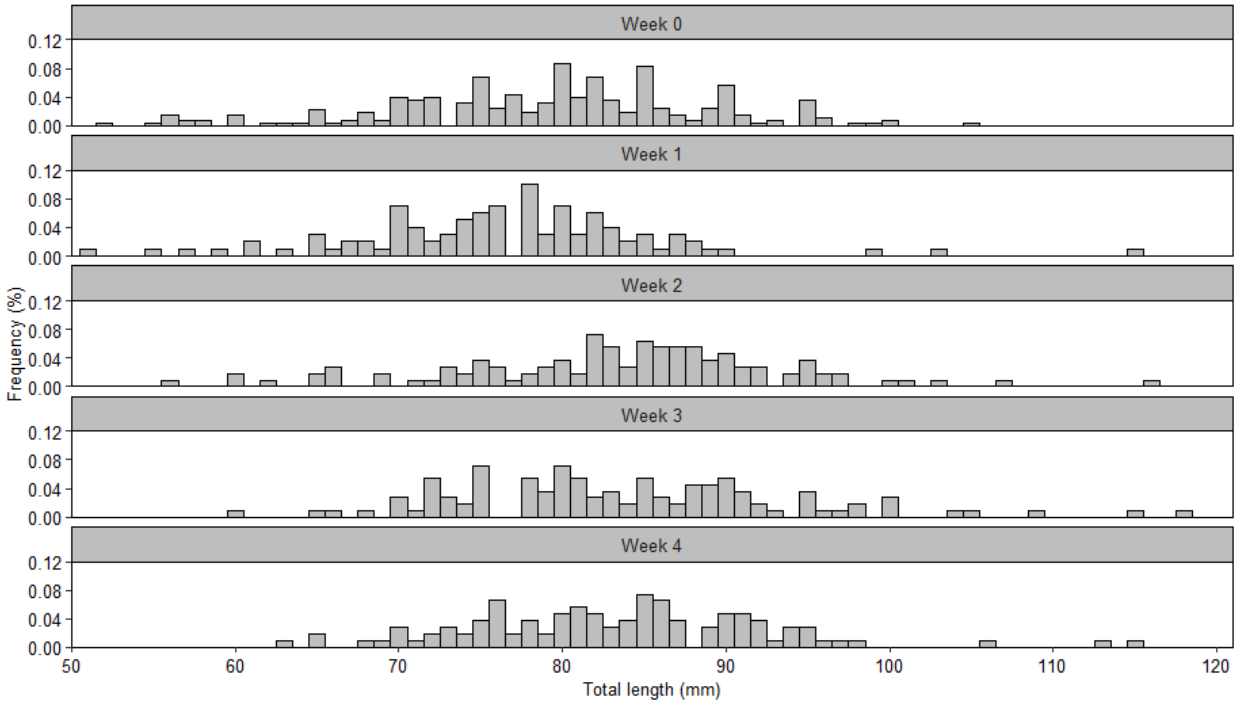

Figure 49. Yellowstone Cutthroat Trout length frequency distribution prior to stocking (Week 0) and collected from fall shoreline electrofishing surveys 1 to 4 weeks after stocking in Henrys Lake, 2018.

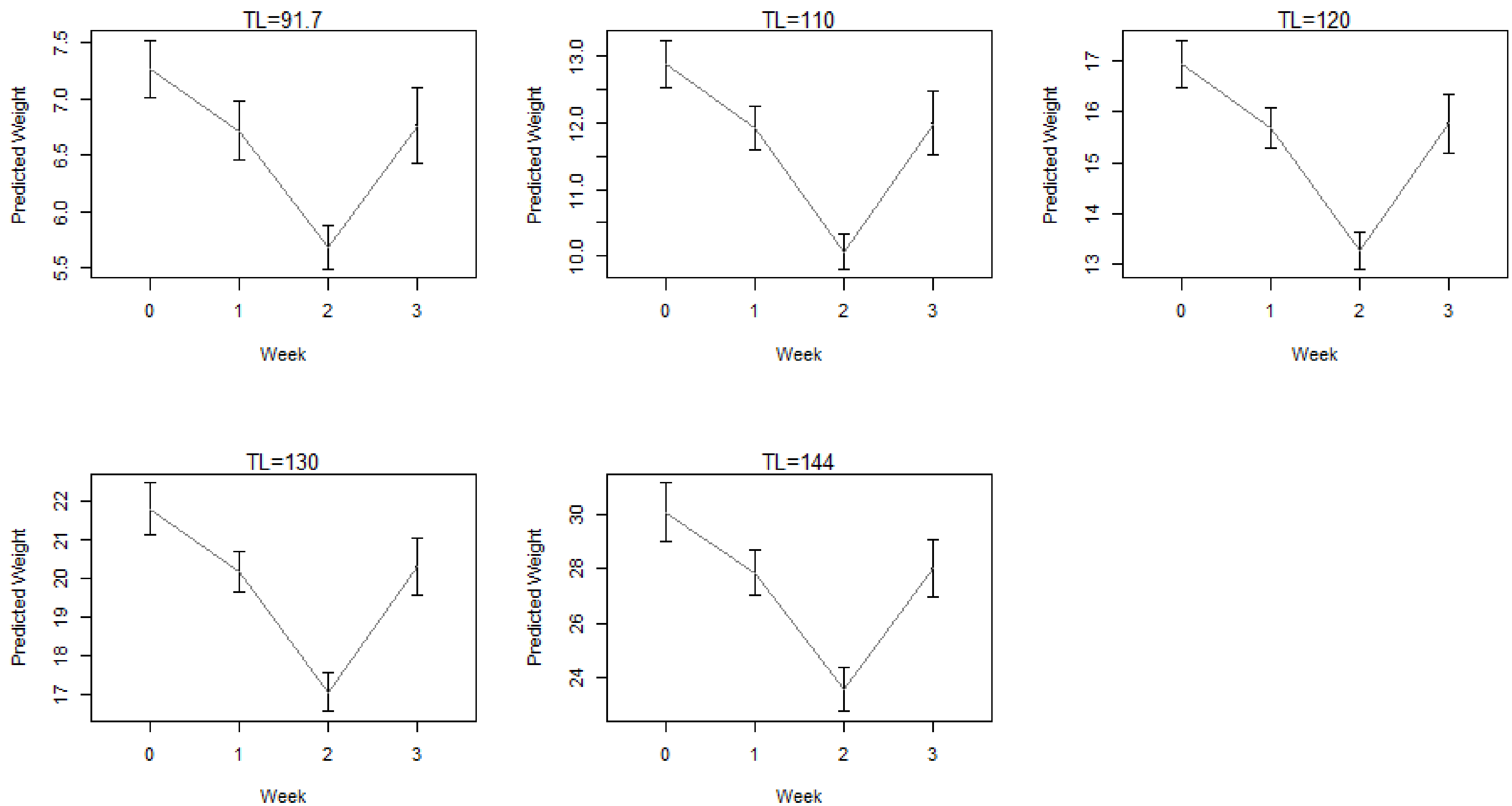

Figure 50. Predicated weights, with 95% confidence intervals, at the 5th, 25th, 50th, 75th, and 95th percentiles without the interaction term of total length (TL) for Brook Trout sampled prior to stocking (Week 0) in September and then from 1 to 3 weeks in October after stocking in Henrys Lake, 2018.

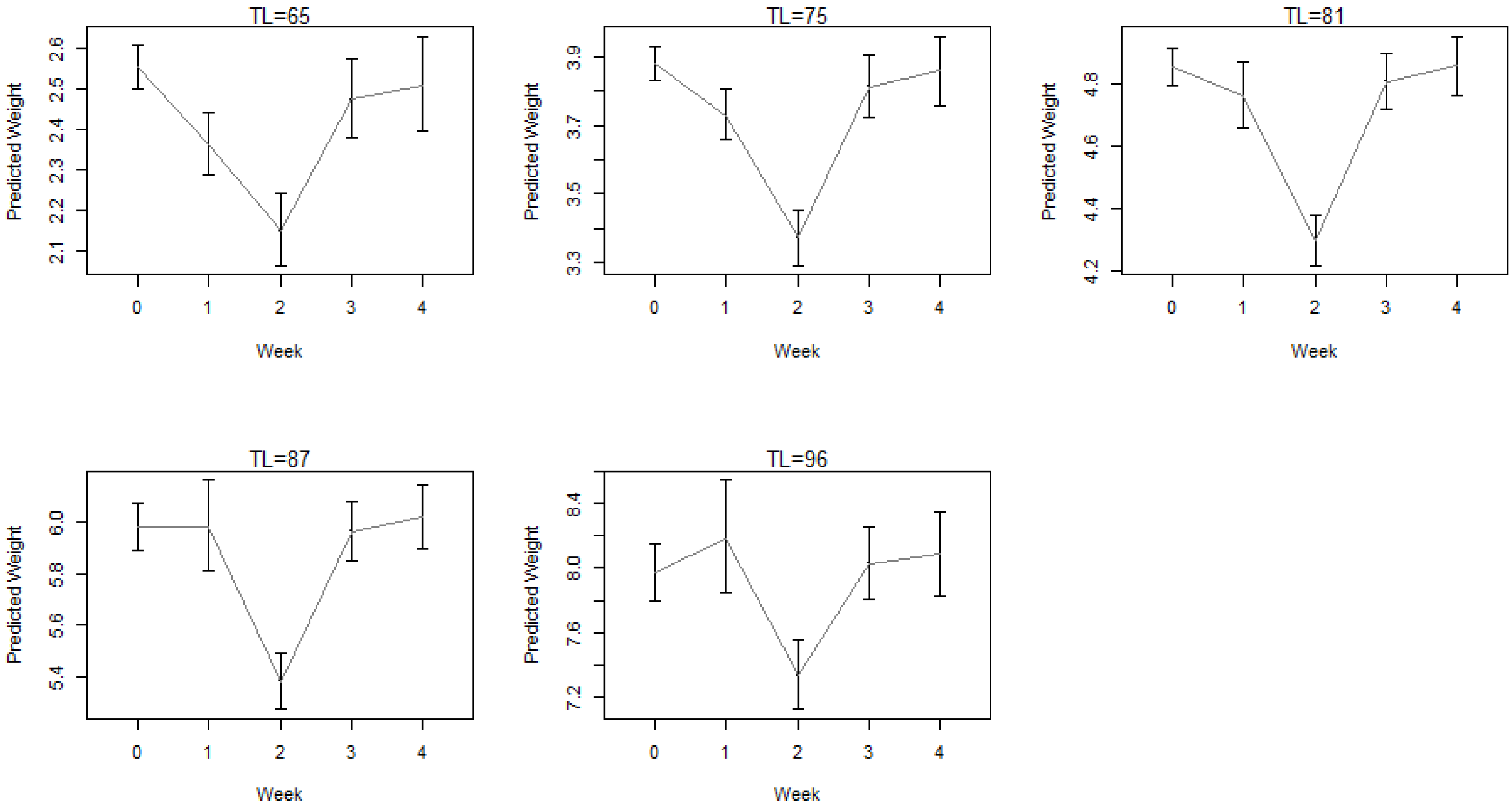

Figure 51. Predicated weights, with 95% confidence intervals, at the 5th, 25th, 50th, 75th, and 95th percentiles with the interaction term of total length (TL) for Yellowstone Cutthroat Trout sampled prior to stocking (Week 0) in September and then from 1 to 4 weeks in October after stocking in Henrys Lake, 2018.

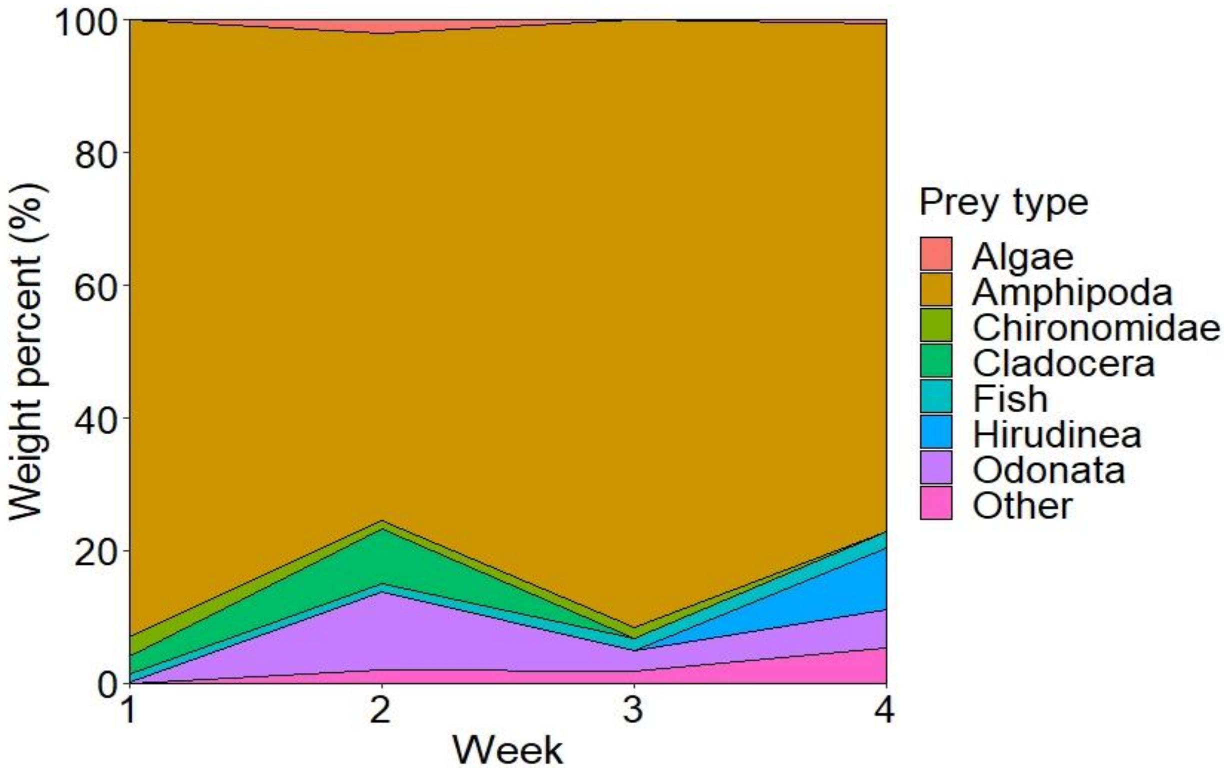

Figure 52. Diet composition of recently stocked Yellowstone Cutthroat Trout represented as mean percent by weight, by week for October in Henrys Lake, 2018.

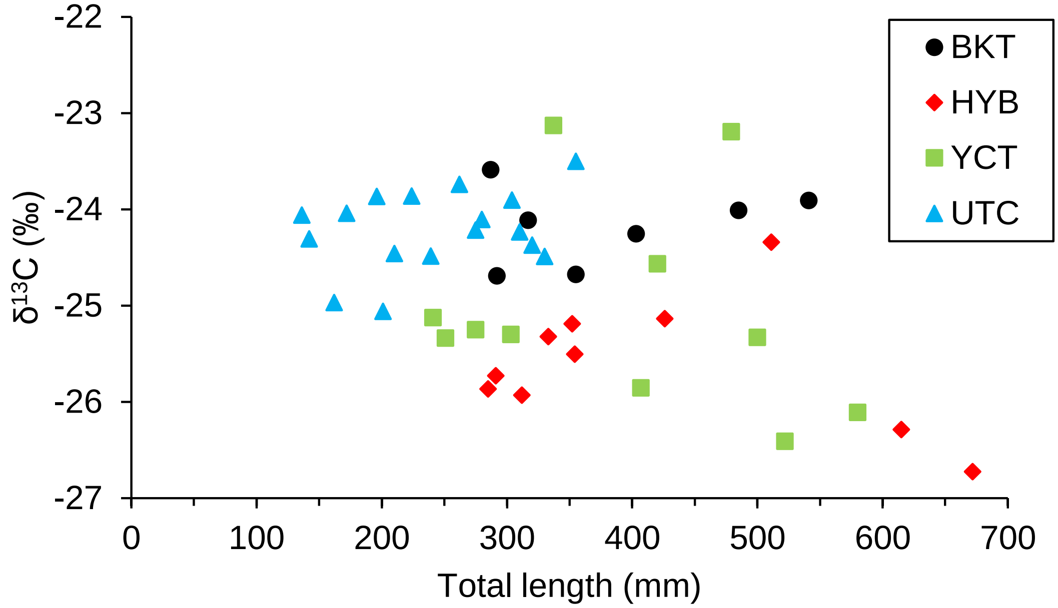

Figure 53. Stable isotope of carbon ($\delta^{13}C$) against total length of Brook Trout (BKT), hybrid trout (HYB), Yellowstone Cutthroat Trout (YCT), and Utah Chub (UTC) in Henrys Lake, 2018.

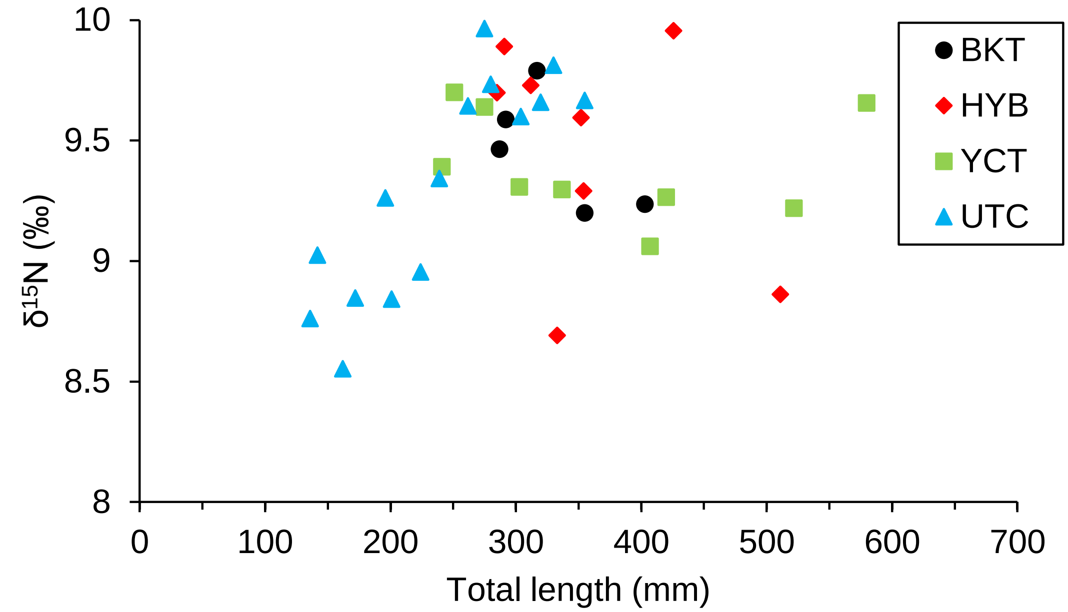

Figure 54. Stable isotope of nitrogen ($\delta^{15}N$), against total length of Brook Trout (BKT), hybrid trout (HYB), Yellowstone Cutthroat Trout (YCT), and Utah Chub (UTC) in Henrys Lake, 2018.

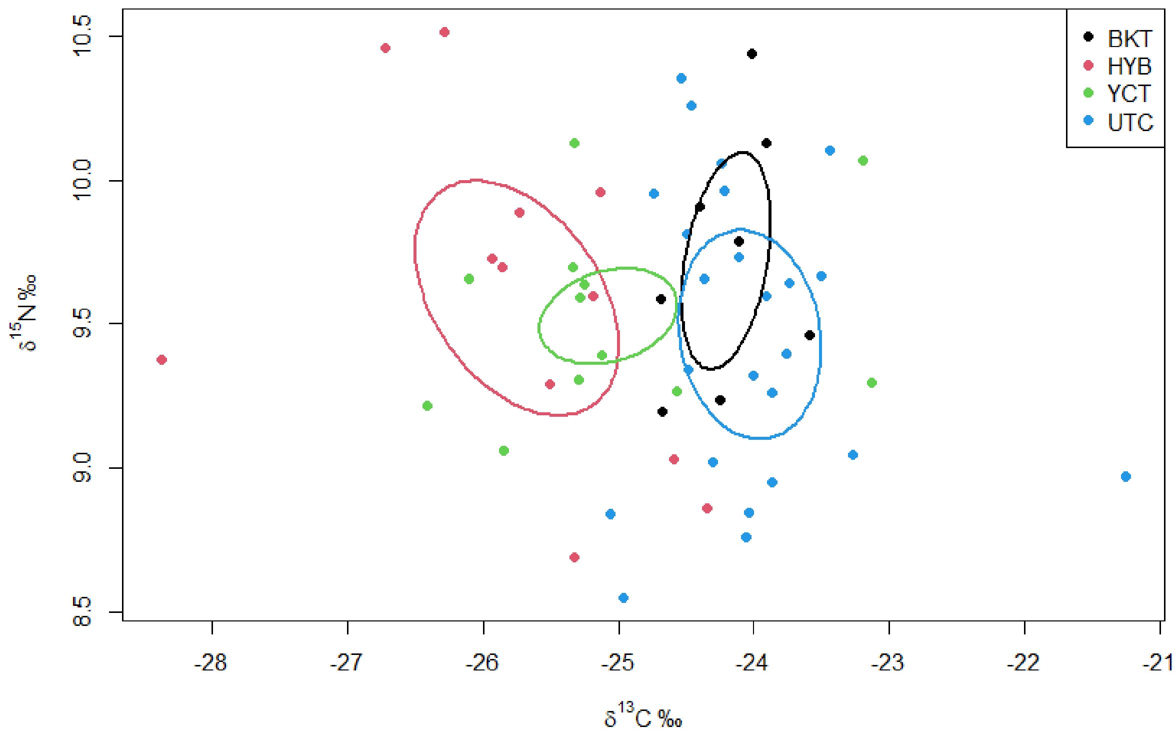

Figure 55. Stable isotope bi-plot of the isotopic niches of Brook Trout (BKT), hybrid trout (HYB), Yellowstone Cutthroat Trout (YCT), and Utah Chub (UTC) in Henrys Lake, 2018. Lines enclose the core ellipse areas (SEA_c), which represents approximately 40% of the core dietary niche for each species.

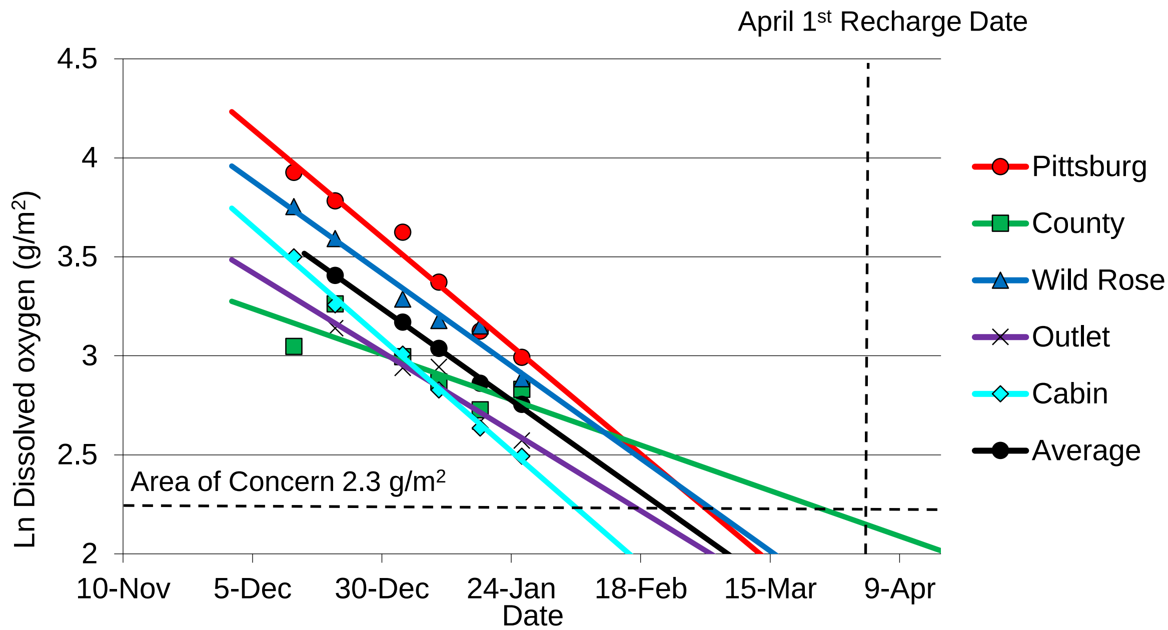

Figure 56. Dissolved oxygen depletion estimates from Henrys Lake, 2017-2018. Dotted lines indicate dissolved oxygen levels indicating area of concern and recharge date (April 1st).

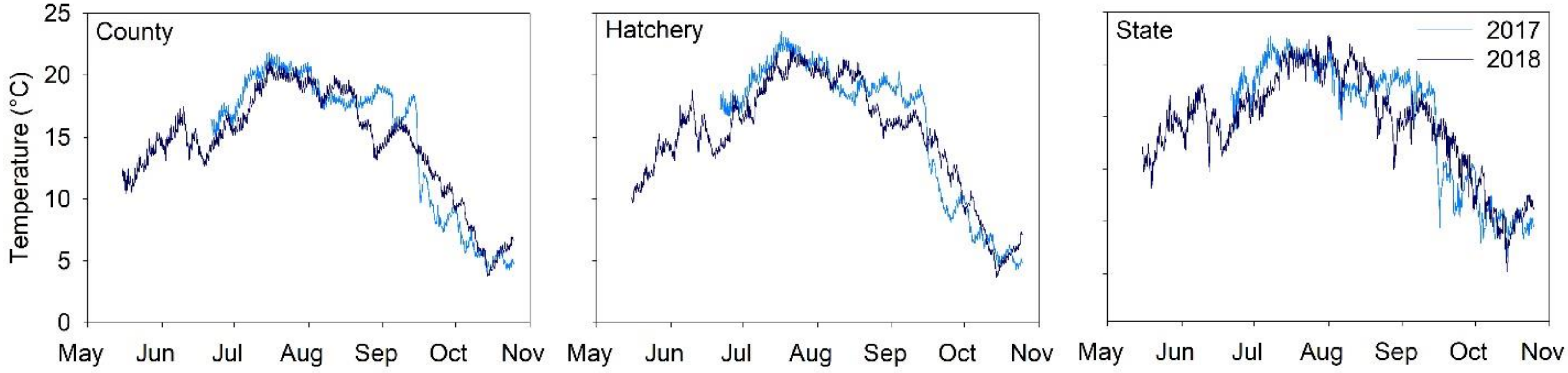

Figure 57. Mean water temperatures (°C) recorded for each site (County boat ramp, IDFG Hatchery, and State boat ramp) and by lake depth (bottom, middle, and surface) for 2017 and 2018 in Henrys Lake.

Appendix D. Gill-net, dissolved oxygen, and temperature logger monitoring locations in Henrys Lake, 2018. All coordinates used NAD27 and are in Zone 12.

Monitoring	Location	UTM E	UTM N
Temperature	County Boat Ramp	465455	4944293
	IDFG Hatchery	469280	4945662
	State Park Boat Ramp	470437	4940912
Gill net	1	467632	4944702
	2	468246	4944893
	3	467603	4940759
	4	467669	4942936
	5	468054	4942408
	6	468196	4940817
Dissolved oxygen	County Boat Dock	466220	4944333
	Wild Rose	467916	4945002
	Outlet	470805	4938870
	Pittsburg Creek	469506	4943349
	IDFG Hatchery	469402	4944997

Appendix E. Historic annual stocking (x 1,000) of Henrys Lake, 1923-2018 for Yellowstone Cutthroat Trout (YCT), hybrid trout (HYB), and Brook Trout (BKT).

Year	YCT	HYB	BKT	Total
1923	40	0	0	40
1924	0	0	0	0
1925	1	0	1	2
1926	140	0	0	140
1927	222	0	0	222
1928	116	0	0	116
1929	0	0	0	0
1930	0	0	0	0
1931	634	0	0	634
1932	170	0	0	170
1933	50	0	0	50
1934	980	0	0	980
1935	632	0	3	635
1936	0	0	0	0
1937	719	0	0	719
1938	753	0	0	753
1939	370	0	0	370
1940	750	0	0	750
1941	0	0	0	0
1942	1,589	0	0	1,589
1943	1,665	0	0	1,665
1944	1,537	0	0	1,537
1945	818	0	0	818
1946	1,670	0	0	1,670
1947	238	0	0	238
1948	584	0	0	584
1949	684	0	2	686
1950	779	5	6	790
1951	2,070	0	0	2,070
1952	610	8	0	618
1953	600	0	0	600
1954	1,223	0	0	1,223
1955	1,243	0	0	1,243
1956	985	0	0	985
1957	640	0	0	640
1958	534	0	0	534
1959	454	0	0	454
1960	1,024	138	0	1,162
1961	1,570	390	0	1,960
1962	1,366	385	0	1,751
1963	1,300	565	0	1,865
1964	1,455	0	0	1,455
1965	1,755	0	0	1,755
1966	1,481	563	0	2,044

Appendix E (continued)

Year	YCT	HYB	BKT	Total
1967	1,159	448	0	1,607
1968	847	132	0	979
1969	111	476	0	587
1970	391	133	0	524
1971	763	184	0	947
1972	834	0	0	834
1973	1,145	0	0	1,145
1974	1,105	0	0	1,105
1975	1,024	0	101	1,125
1976	862	200	167	1,229
1977	825	200	137	1,162
1978	946	179	89	1,214
1979	1,134	125	96	1,355
1980	1,040	32	91	1,163
1981	2,251	146	20	2,417
1982	2,442	242	18	2,702
1983	2,179	229	22	2,429
1984	2,041	135	0	2,175
1985	995	33	111	1,139
1986	989	292	0	1,281
1987	663	256	0	919
1988	1,011	312	0	1,323
1989	1,090	251	95	1,436
1990	1,001	200	157	1,358
1991	1,326	201	129	1,656
1992	943	203	189	1,336
1993	1,060	217	112	1,388
1994	1,048	201	115	1,363
1995	1,381	144	136	1,662
1996	661	200	196	1,057
1997	1,237	180	204	1,621
1998	1,047	204	207	1,459
1999	1,249	204	0	1,453
2000	978	0	0	978
2001	991	135	0	1,126
2002	1,107	331	0	1,438
2003	1,634	264	99	1,996
2004	921	38	117	1,077
2005	851	201	152	1,204
2006	1,124	150	107	1,381
2007	1,394	146	104	1,644
2008	1,254	196	198	1,648
2009	1,382	220	171	1,773
2010	1,326	138	93	1,557
2011	1,127	205	100	1,432
2012	768	221	101	1,090
2013	756	213	110	1,079
2014	729	167	83	979

Appendix E (continued)

Year	YCT	HYB	BKT	Total
2015	955	167	71	1,193
2016	1,105	177	5	1,288
2017	1,012	212	202	1,426
2018	1,160	239	105	1,504

RIRIE RESERVOIR

ABSTRACT

We conducted our fourth year of monitoring the kokanee *Oncorhynchus nerka* population in Ririe Reservoir using gill nets suspended in the thermocline. Average gill net catch of 89 kokanee per net night (± 39.1, 95% CI), which was slightly less than 2017 (107 per net night ± 16). We observed thermal marks on kokanee otoliths suggesting that three different age classes exist and ranged from 108 to 378 mm (TL). Otolith thermal marks suggest limited recruitment of wild kokanee with stocking maintaining the fishery. Kokanee composed a substantial portion of the overall species composition (32%), but the majority of gill net catch was composed of Yellow Perch *Perca flavescens* (61%). Continued monitoring of kokanee will allow managers to adjust stocking rates when appropriate in an effort to produce a quality fishery with adequate angler catch rates obtained through creel surveys. We also conducted boat electrofishing in June to assess the Smallmouth Bass *Micropterus dolomieu* population. The electrofishing effort yielded 56 Smallmouth Bass per hour (± 20.1), which was a higher point estimate than the last survey conducted in 2014 of 35 Smallmouth Bass per hour (± 14.4), but not a statistically different estimate. Smallmouth Bass ranged in size from 61 to 335 mm (TL). Smallmouth Bass abundance has increased since the recent liberalizations of the minimum size limit harvest (> 305 mm TL) in Ririe Reservoir. Smallmouth Bass in Ririe Reservoir continue to experience slow growth rates due to the short growing season.

Authors:

John Heckel
Regional Fisheries Biologist

Jon Flinders
Regional Fisheries Biologist

Brett High
Regional Fisheries Manager

INTRODUCTION

Ririe Reservoir is located on Willow Creek, approximately 32 km east of Idaho Falls (Figure 58). Ririe Dam was constructed in 1977, with the reservoir being filled to capacity for the first time in 1978. Ririe Reservoir is fed by approximately 153 km of streams in the Willow Creek drainage, and has a total storage capacity of 124,015 mega liters (100,541 acre-feet). Ririe Reservoir is approximately 17-km long, and is less than 1.5-km wide along the entire length, with a surface area of approximately 631 hectares, and a mean depth of 19.5 m. Ririe Reservoir is managed primarily for flood control and irrigation storage (BOR 2001).

Ririe Reservoir supports a popular fishery for kokanee *Oncorhynchus nerka*, Yellowstone Cutthroat Trout *O. clarkii bouvieri* (YCT), Rainbow Trout *O. mykiss* (RBT), Smallmouth Bass *Micropterus dolomieu* (SMB), and Yellow Perch *Perca flavescens* (YLP). Utah Chub *Gila atraria* and Utah Sucker *Catostomus ardens* are also found in Ririe Reservoir in relatively high numbers. In 2013, creel surveys showed angler use was approximately 43,000 hours and has averaged 47,000 hours of angler use over the last 20 years (High et al. 2015). Since 1990, fingerling kokanee have been stocked annually in the spring. In 2004, kokanee stocking rates were increased from approximately 70,000 to 210,000 in an effort to improve angler catch rates and meet increased angler demand. The Idaho Department of Fish and Game (IDFG) Fisheries Management Plan for 2013-2018 directs managers to maintain kokanee catch rates of 1.0 fish/h (IDFG 2013). We evaluate this management directive by conducting periodic creel surveys on the reservoir. Over the last five years (2014-2018), kokanee stocking numbers were increased an additional 50,000 to 110,000 to approximately 260,000 to 320,000 fingerlings per year. Up until 2012, approximately 18,000 catchable YCT were stocked annually to provide additional angling opportunities. Following relatively poor performance of those fish, they were replaced by similar numbers of sterile Rainbow Trout. Based on creel results in 2013, anglers caught an estimated 14,128 of the 18,000 (78%) Rainbow Trout stocked (High et al. 2015). The high angler use of Rainbow Trout observed in 2013 suggests that hatchery Rainbow Trout are providing a diverse angling opportunity as well as meeting angler expectations. A YLP fishery also exists in Ririe Reservoir and has become more popular over the past several years as spring reservoir levels have remained high with a resultant increase in condition and size of perch (Schoby et al. 2010). A self-sustaining population of SMB has developed from introductions into Ririe Reservoir from 1984 to 1986. Although limited by the short growing season at this latitude and altitude, SMB provide angling diversity for anglers and are valued by the angling public in the Upper Snake Region.

Walleye were illegally introduced to Ririe Reservoir and were first discovered in 2008. In 2009, annual monitoring of the Walleye population began to determine the status of the walleye population and changes to the existing fishery. Fall Walleye Index Netting (FWIN) began in 2010 and ran consecutively until 2017. We found that the Walleye population was low and stable (e.g., 0.52 Walleye/net night from 2010 to 2017; unpublished IDFG data), so we began monitoring triennially.

OBJECTIVES

Use annual summer gill netting to index relative abundance as well as describe size structure and growth of kokanee in Ririe Reservoir.

Index relative abundance and describe growth of SMB in Ririe Reservoir to evaluate potential population changes after removal of restrictive regulations (e.g. minimum size limit).

METHODS

We surveyed the kokanee population from June 12 to 14, 2018, during the new moon, using experimental gill nets with a neutrally buoyant design suspended in the thermocline. We used a water quality meter (YSI Inc., Yellow Springs, Ohio) to take water temperature at the surface and every subsequent meter down the water column until the thermocline was identified by a several degree water temperature difference from the previous depth. Experimental gill nets measured 37-m long by 6-m deep with 12 panels that were 3 m in length with two panels for each mesh size randomly positioned. The mesh sizes of the panel were 25-, 38-, 51-, 64-, 76-, and 102-mm bar mesh monofilament. We excluded smaller meshes (13 and 19 mm) typically found in statewide standardized kokanee nets in an effort to minimize bycatch of YLP. We set nets at dusk and retrieved them the following morning. Sites were randomly selected by overlaying a grid system (100 × 100 m) in mapping software (IDFG 2012). For site selection, Ririe Reservoir was stratified into three strata (lower, middle, upper). The nets were set in depths ranging from 10 to 16 m to ensure adequate coverage in the thermocline. All fish captured were identified, measured for total length (TL) to the nearest millimeter, and weighed to the nearest gram. We calculated CPUE for each species as fish per net night.

We also examined length-at-maturity for kokanee. For females, each ovary was assigned a maturity stage of either immature (small, translucent) or mature (large, orange, opaque). Logistic regression was used to fit sigmoid curves to the proportion mature by length in the equation,

$$p_{x1} = e^{(b_0+b_1+x_1)}/(1+e^{(b_0+b_1+x_1)}),$$

where p is the probability that a fish is mature in a given length (mm) interval x_1, b_0 and b_1 are parameters that define the shape and location of the fitted sigmoid curve. The predicted length of 50% maturity was calculated as, $L_{50} = -b_0/b_1$.

We removed sagittal otoliths from kokanee collected from gill netting for age and growth analysis. We also evaluated success of the kokanee stocking program via otolith thermal mass-marking (Volk et al. 1990). Prior to stocking, kokanee were reared at Cabinet Gorge Hatchery where all kokanee fry received a thermally-induced otolith pattern at the swim-up stage of development. Differential temperature was approximately 5°C. We examined otolith growth rings for distinctive thermal bands for each year class. After removal, all otoliths were cleaned on a paper towel and stored in individually labeled envelopes. We sectioned, polished and read otoliths in cross-section view with transmitted light. The von Bertalanffy (1938) growth model was used to fit length at age:

$$l_t = L_\infty(1 - e^{-K(t-t_0)})$$

where l_t is length at time t, L_∞ is the asymptotic length, K is a growth coefficient, and t_0 is a time coefficient at which length would theoretically be 0. The model was fitted to length-at-data by using the nonlinear model (NLIN) procedure in program R. We assigned ages to individual kokanee from the subsample of aged fish using the Isermann and Knight (2005) method using the FSA package in program R.

We used pulsed direct current (DC) boat-mounted electrofishing gear to sample the littoral fish community in Ririe Reservoir from July 9 to 11, 2018. We used two netters to collect fish and electrofishing surveys began each night at dusk. A survey consisted of 10 minutes (600 seconds) of electrofishing at each site (IDFG 2012). Potential sites were identified in each of the three strata by measuring 500-m, continuous sections along the shoreline, which is approximately the maximum length of shoreline that can be electrofished in 10 minutes (IDFG 2012). These potential sites, each 500-m long, were assigned a unique number and numbers were selected randomly for each strata. The sites were randomly selected in 2014 and we sampled these same previously randomly selected sites. Fish that we collected were identified to species and measured for total length before being released in the general location of capture. We calculated CPUE of for each species as number of fish caught per hour.

We kept a subsample of 10 fish per 10-mm length group of SMB and removed sagittal otoliths for age and growth analysis. After we removed otoliths, all otoliths were cleaned on a paper towel and stored in individually-labeled vials. We estimated ages on whole otoliths by counting annuli under a dissecting microscope at 40x power. We submerged otoliths in water and read them in whole view when clear, distinct growth rings were present. We used a von Bertalanffy (1938) growth model to fit length at age. We estimated the mortality rate (*Z*) for SMB from ages 1 to 8 using catch curve analysis. Age-0 SMB ($\leq$ 120 mm) were excluded from the analysis due to lack of recruitment to our sampling gear. We calculated proportional stock density (PSD) and relative stock density of preferred sized fish (RSD-P) for all game fish (Anderson and Neumann 1996).

RESULTS

We collected 2,494 fish represented by kokanee, RBT, SMB, Utah Chub, Utah Sucker, YCT, Walleye, and YLP from gill netting and electrofishing (Table 26; Figure 59). We captured 89.4 kokanee per net night (± 39.1) in gill nets and was similar to the average from 2015 to 2017 (Figure 60). However, CPUE of age-0 kokanee in the nets was extremely low in 2018 with very few collected. Kokanee ranged in size from 108 to 378 mm with a mean of 279 mm (± 3.8; Figure 61). Kokanee mean relative weight was 93.0 (± 0.7) and exhibited no increase in condition with size (r^2 = 0.24; Figure 62). Kokanee PSD and RSD-P were 64 and 57, respectively. We examined thermal marks on 52 kokanee to determine ages and wild to hatchery contributions to the fishery. All otoliths exhibited thermal marks. Average total length of age-0, age-1, and age-2 kokanee was 119 mm (± 23.3), 215 mm (± 2.4), and 320 mm (± 1.3), respectively (Figure 63). We examined 286 kokanee for maturity analysis, of which 89 and 197 were females and males, respectively. From the logistic regression curve (Female maturity proportion = $1 + e^{(-(-18.67\ +\ 0.070\ \times\ TL))}$), we estimated that female kokanee were 1% mature (L_1) at approximately 202 mm and 50% mature (L_{50}) at approximately 268 mm (Figure 64). For male kokanee, from the logistic regression curve (Male maturity proportion = $1 + e^{(-(-12.78\ +\ 0.050\ \times\ TL))}$), we estimated that 1% mature (L_1) at approximately 166 mm and 50% mature (L_{50}) at approximately 260 mm. Maturity analysis, of kokanee males and females, has been similar every year since 2015 (Figure 65).

Total electrofishing effort was 4 hours across 24 sites. Smallmouth Bass mean length was 130 mm (±7.0) and ranged in size from 61 to 335 mm (Figure 66). Mean electrofishing CPUE for bass was 56 bass per hour (± 20.1; Figure 67). The single kokanee sampled was 210 mm TL and represents a mean electrofishing CPUE of 0.3 kokanee per hour. Rainbow Trout mean length was 290 mm (± 18.6; range 196-330 mm), with a mean electrofishing CPUE of 5 RBT per hour (± 2.9). Yellow Perch mean length was 174 mm (± 2.5; range 73-227 mm), with a mean electrofishing CPUE of 111 YLP per hour (± 45.6). The lone Walleye we collected was 176 mm, which represents a mean electrofishing CPUE of 0.3 Walleye per hour. The mean relative weight

(W_r) of SMB was 99 (± 2.7), with decreasing relative weight with increasing size (Figure 68). For catch curve analysis and length-at-age, we aged 108 SMB. We estimated SMB measuring 61 to 335 mm were from 0 to 7 years old. Mean length-at-age for age-1 fish was 124 mm (± 3), and 161 mm (± 4), 195 mm (± 4), 229 mm (± 6), 260 mm (± 6), 289 mm (± 9), and 316 mm (± 13) for age-2 through age-7, respectively. Smallmouth Bass grew toward their asymptotic length of L_∞ = 785 mm (520-1,997; 95% CI) at an instantaneous rate of growth (K) = 0.06/year (0.02-0.10; 95% CI). Smallmouth Bass natural mortality from age-1 to age-7 was 41% annually (Figure 69).

DISCUSSION

The catch rate for kokanee in gill nets was above the average from 2015 to 2017, but we captured very few age-0 kokanee in gill nets, which is likely a result of a change in stocking regime this year. Thermal marks were observed on kokanee otoliths, suggesting that this population is highly dependent on stocking. Following a statewide shortage of early-run kokanee eggs, we did not receive our complete stocking request for kokanee. Instead, 88% of our stocking request was comprised of, late-run kokanee. This could possibly lead to lower angler catch rates during the next couple of years if late-run kokanee survive or grow at lower rates. We will evaluate the survival and recruitment of this year class in our annual gill-net surveys. Alternatively, because kokanee experience density-dependent growth, lower numbers may lead to better body condition in the population. The current trend in relative weight for kokanee in Ririe Reservoir is declining as kokanee grow longer, i.e., kokanee get skinnier as they grow longer. If anglers experience lower catch rates for kokanee in upcoming years, a strong YLP population may provide anglers with alternative fishing opportunities.

We compared growth rates of SMB to the statewide average developed by Dillon (1996) and found SMB growth was much slower in Ririe Reservoir. The lower growth rates are likely due to the differences in latitude and growing season (i.e. colder water temperatures) in southeastern Idaho. The slow growth rates may limit the effectiveness of imposing a minimum length limit and we did not catch many SMB larger than 254 mm. Furthermore, the relative weight of SMB in Ririe declines as a bass grows longer, suggesting that there may be prey limitations for larger bass in Ririe. Minimum length limits prohibit harvest of fish less than a specified length and have been implemented to reduce harvest and improve angler catch rates (i.e. increased abundance) and size structure or as a tool to ensure fish remain in the system long enough to spawn before being available to angler harvest. Reductions in harvest often may not be popular among harvest-oriented anglers, but are very popular with catch and release anglers. A minimum length limit would likely improve the size structure of the fishery if growth was relatively fast and angling mortality was high. Conversely, slow growth as observed in this study might prevent increases in size structure if most fish are lost to natural mortality before they reach the minimum harvest length. We estimated mortality at 41%, which is less than our estimate from 2014 (i.e., 65%).

Although we did not collect many SMB >254 mm in our electrofishing surveys, past surveys indicate larger SMB are present, but in limited abundance. Gill-netting efforts in 2013 collected two SMB of 341 mm and 421 mm. Electrofishing generally selects for larger-sized fish due to their larger surface area. However, the steep canyon walls in Ririe Reservoir may make littoral zone electrofishing less efficient than electrofishing in shallower environments. Also, larger SMB may be occupying deeper waters that we were ineffective in sampling with electrofishing gear. Even though we did not capture a high abundance of larger SMB, the CPUE for Smallmouth was the second highest on record in our electrofishing surveys. As such, Ririe is a diverse fishery that provides anglers with opportunities to target multiple species and harvest opportunities of all species in the reservoir. Future monitoring efforts should consider an alternative method in tandem with electrofishing to target a more representative size distribution of SMB. For example, combining electrofishing at day and night combined with following lowland lake gill netting protocols. Power analysis that was conducted in 2014 suggests that at least 24 sites are necessary for future monitoring trends to acquire SMB electrofishing CPUEs that are within 80% confidence limits and ± 25% of the mean (Flinders et al. 2016). Sampling at a higher level than this is not feasible with current manpower and funding availability, nor is it necessary.

RECOMMENDATIONS

1. Continue annual early summer gill net monitoring to evaluate kokanee abundance and growth.

2. Evaluate stocking rates of kokanee to provide maximum benefits to anglers.

3. Monitor SMB abundances on a five-year cycle.

Table 26. Gill net catch and CPUE (number/net night) for nine gill nets and electrofishing catch and CPUE (number/hr) for 24 sites in Ririe Reservoir. Confidence intervals are in parentheses (± 95%).

	Gill net catch	Gill net CPUE	Electrofishing catch	Electrofishing CPUE
Kokanee	805	89.4 (39.1)	1	0.3 (0.5)
Rainbow Trout (hatchery)	5	0.6 (0.6)	18	5 (2.9)
Smallmouth Bass	3	0.3 (0.8)	223	55.8 (20.1)
Yellowstone Cutthroat Trout	1	0.1 (0.3)	0	0
Yellow Perch	1,519	168.8 (0.3)	443	110.8 (45.6)
Walleye	0	0	1	0.3 (0.5)
Utah Chub	1	0.1 (0.3)	7	1.8 (2.6)
Utah Sucker	160	17.8 (11.8)	203	50.8 (24.7)
Total	2,494	277.1 (33.4)	896	224.8 70.1)

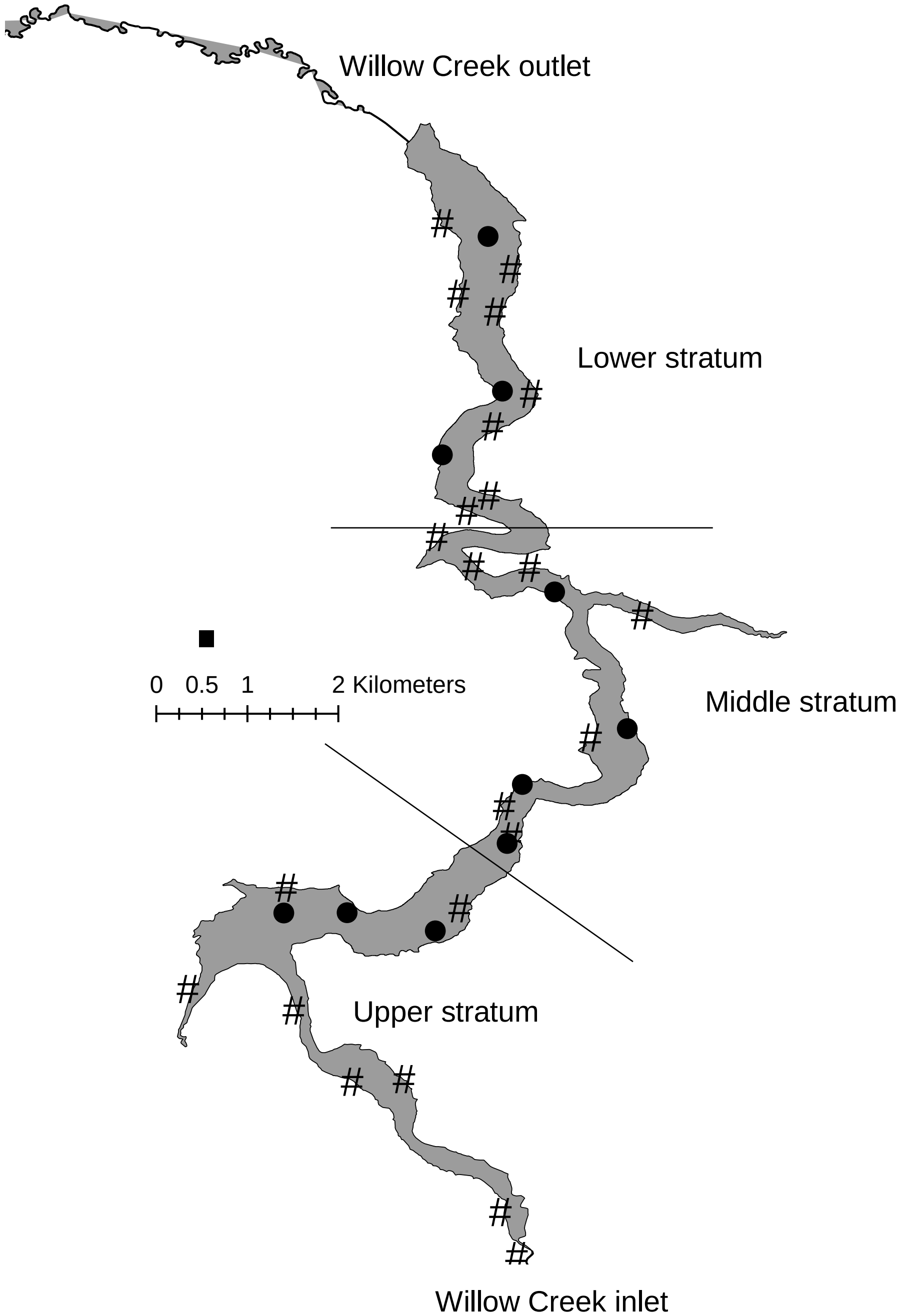

Figure 58. Ririe Reservoir with gill netting locations for kokanee represented by black circles, and electrofishing sites for Smallmouth Bass represented by black triangles.

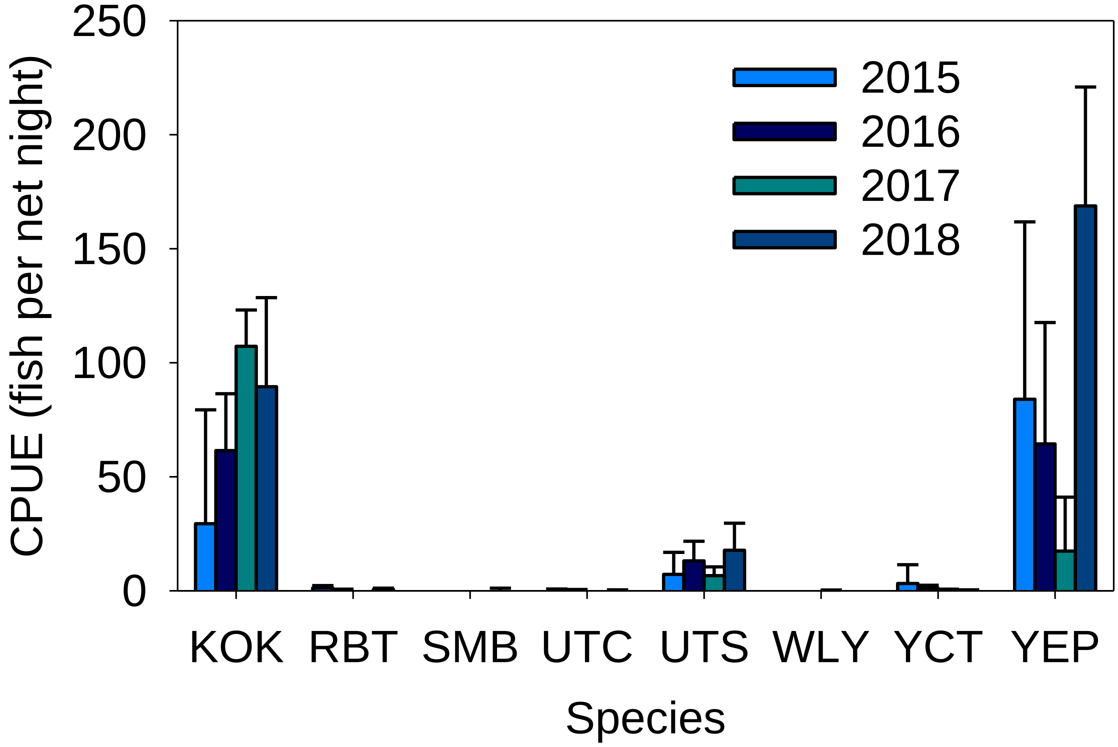

Figure 59. Catch per unit effort (fish per net night) from gill nets for kokanee (KOK), Rainbow Trout (RBT), Smallmouth Bass (SMB), Utah Chub (UTC), Utah Sucker (UTS), Walleye (WLY), Yellowstone Cutthroat Trout (YCT), and Yellow Perch (YEP) in Ririe Reservoir, during 2015-2018. Error bars represent 95% confidence intervals.

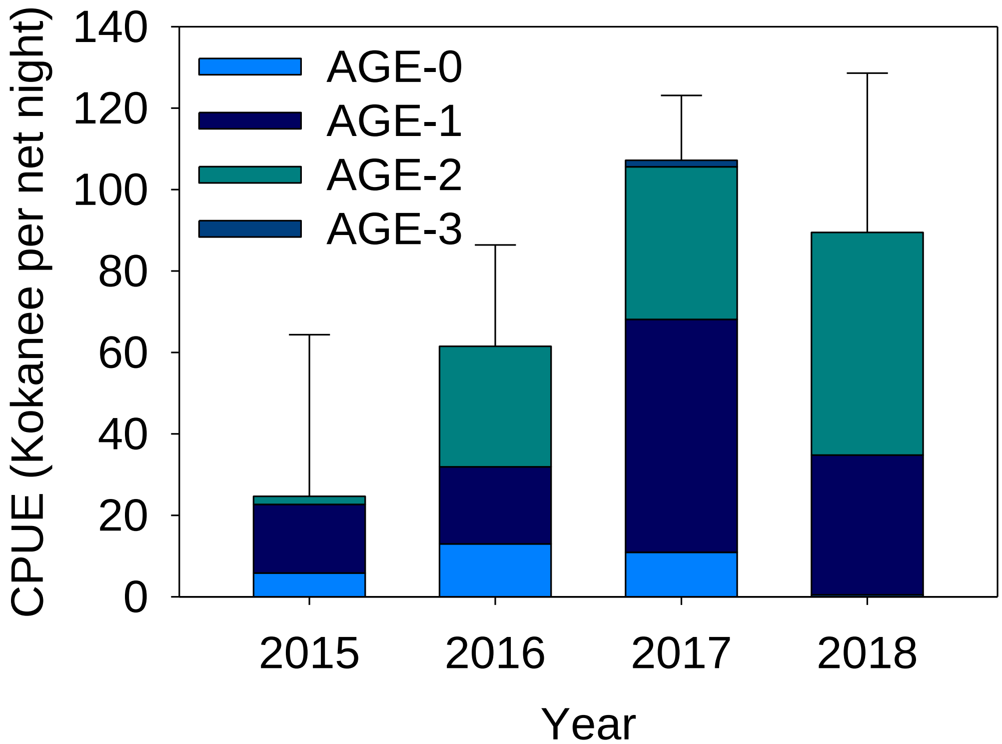

Figure 60. Kokanee catch per unit effort by age in Ririe Reservoir from 2015-2018. Error bars represent 95% confidence intervals.

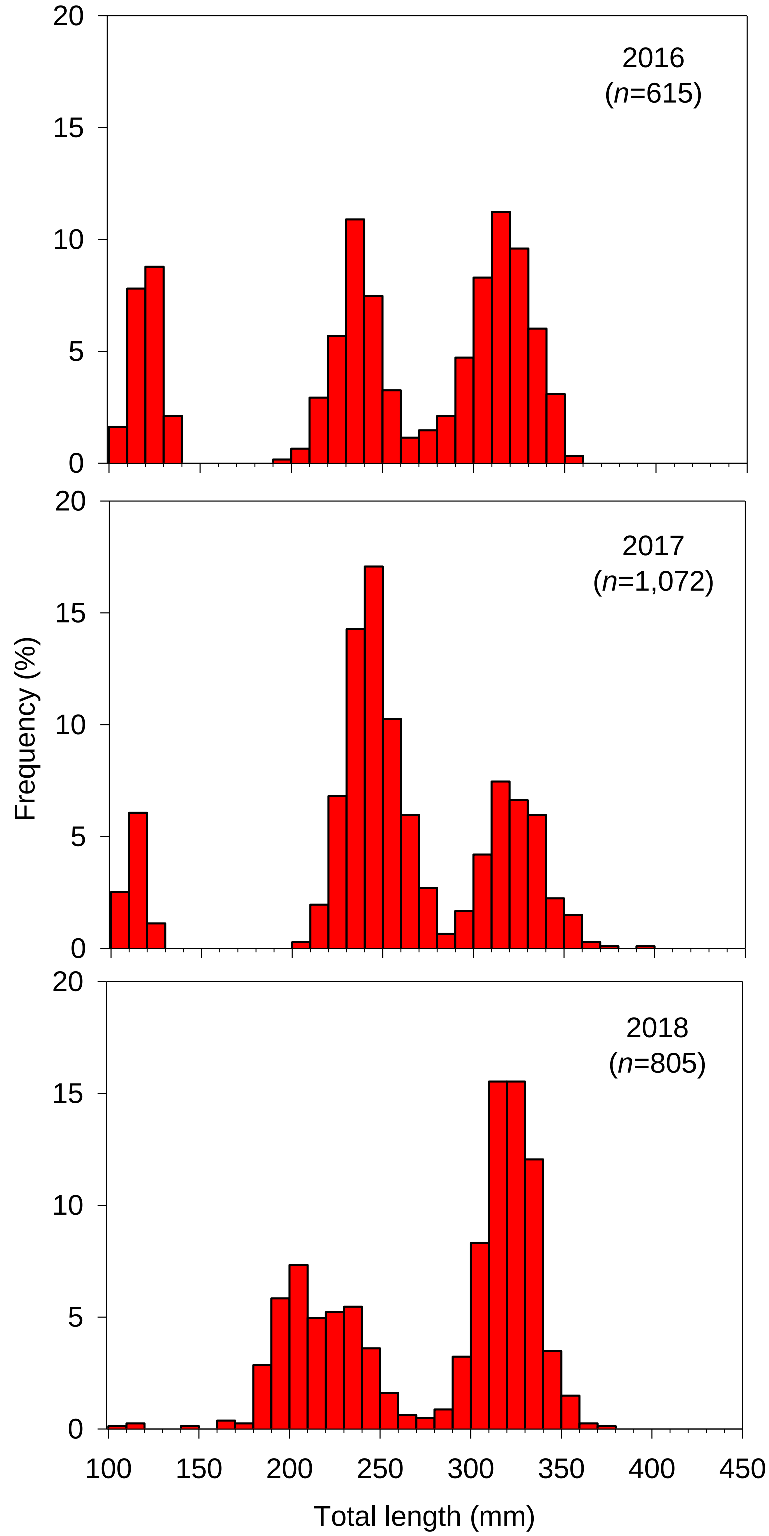

Figure 61. Length-frequency histogram of the kokanee from gill netting in Ririe Reservoir from 2016-2018.

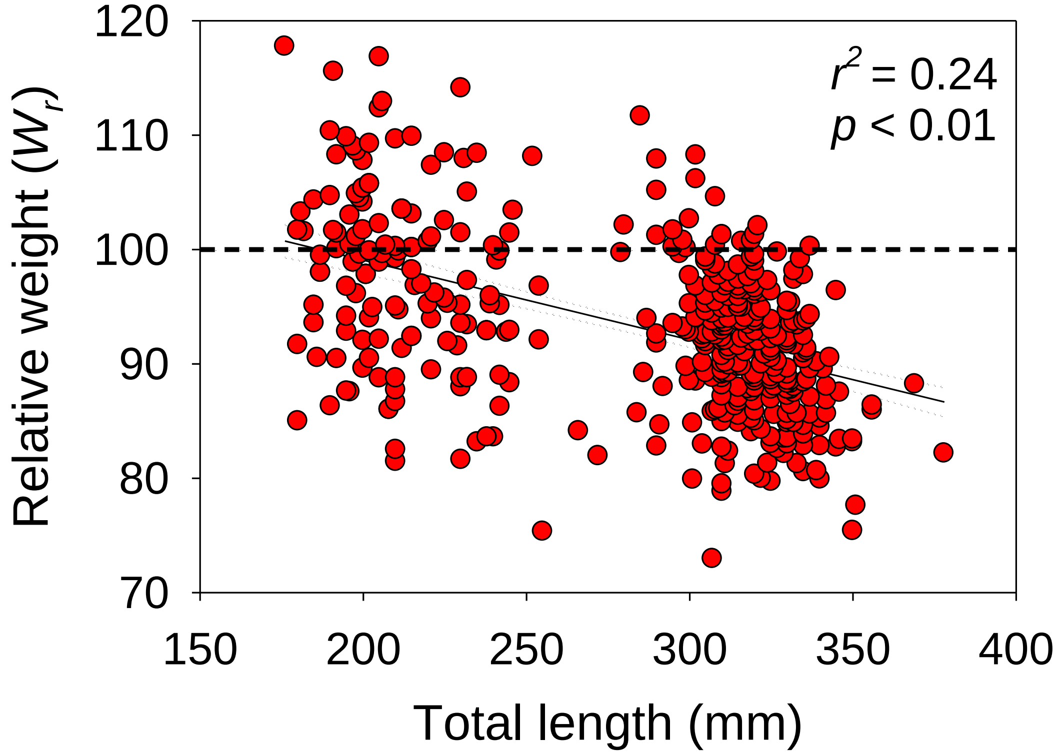

Figure 62. Relative weight (W_r) of kokanee by total length (mm) in Ririe Reservoir, 2018.

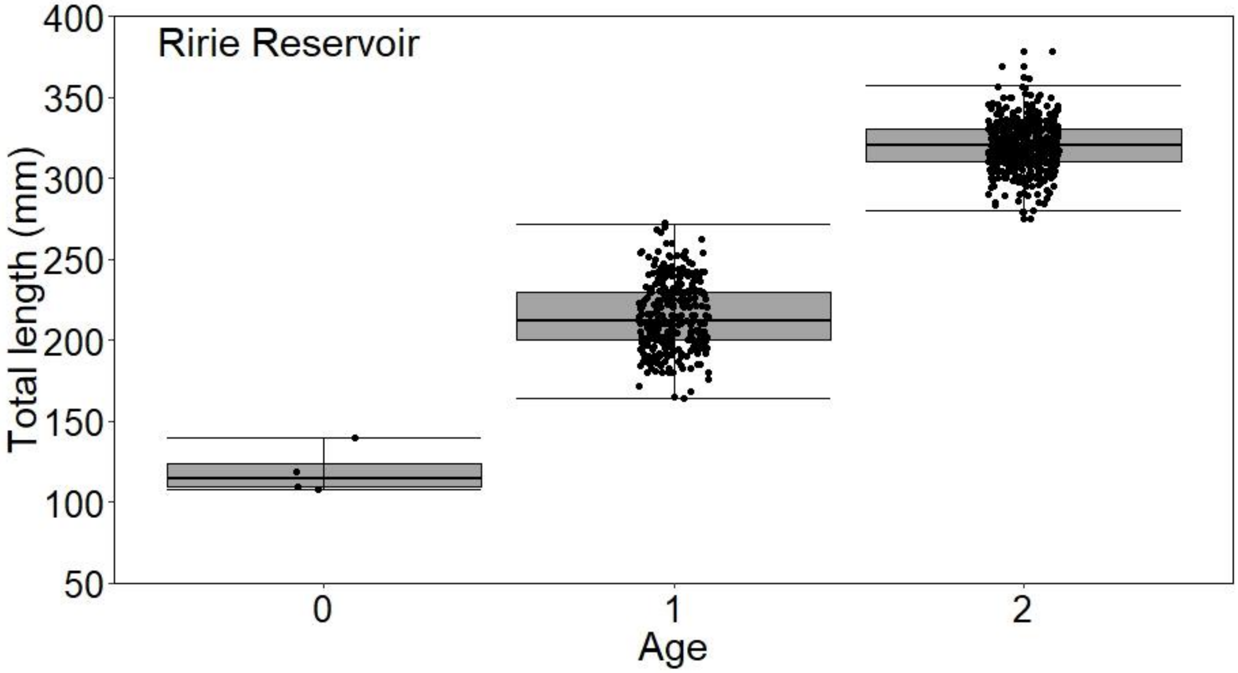

Figure 63. Scatter plot and box plot showing the distribution of kokanee total length (mm) by age collected from gill nets in 2018. The bottom and top of the box indicate the first (Q1) and third (Q3) quartiles, and middle line in box represents the median.

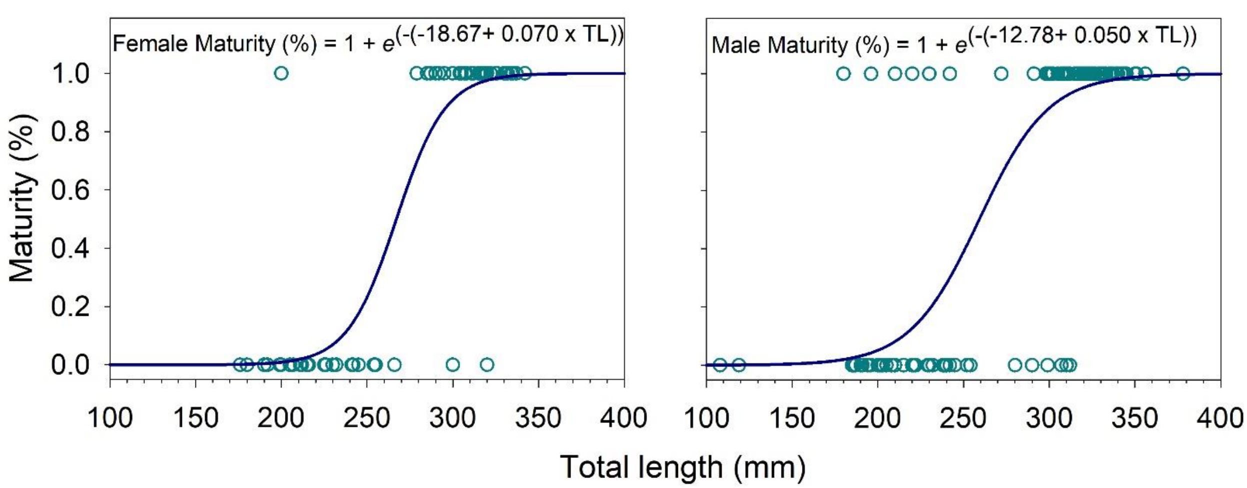

Figure 64. Proportion mature (1 = mature, 0 = immature) by total length with a fitted logistic regression curve of female and male kokanee collected in gill nets at Ririe Reservoir in the summer of 2018.

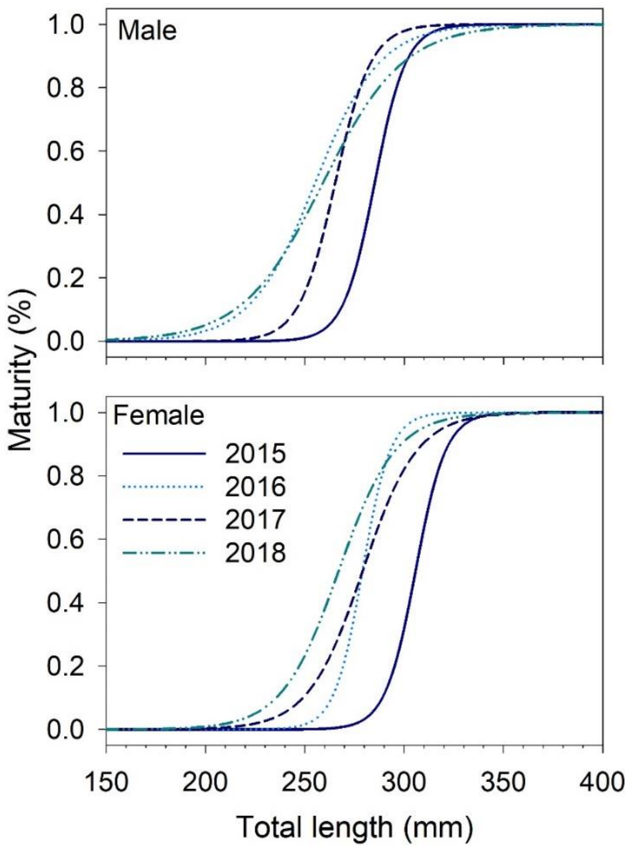

Figure 65. Proportion mature (1 = mature, 0 = immature) by total length with a fitted logistic regression curve of male and female kokanee collected in gill nets in 2015, 2016, 2017, and 2018 at Ririe Reservoir.

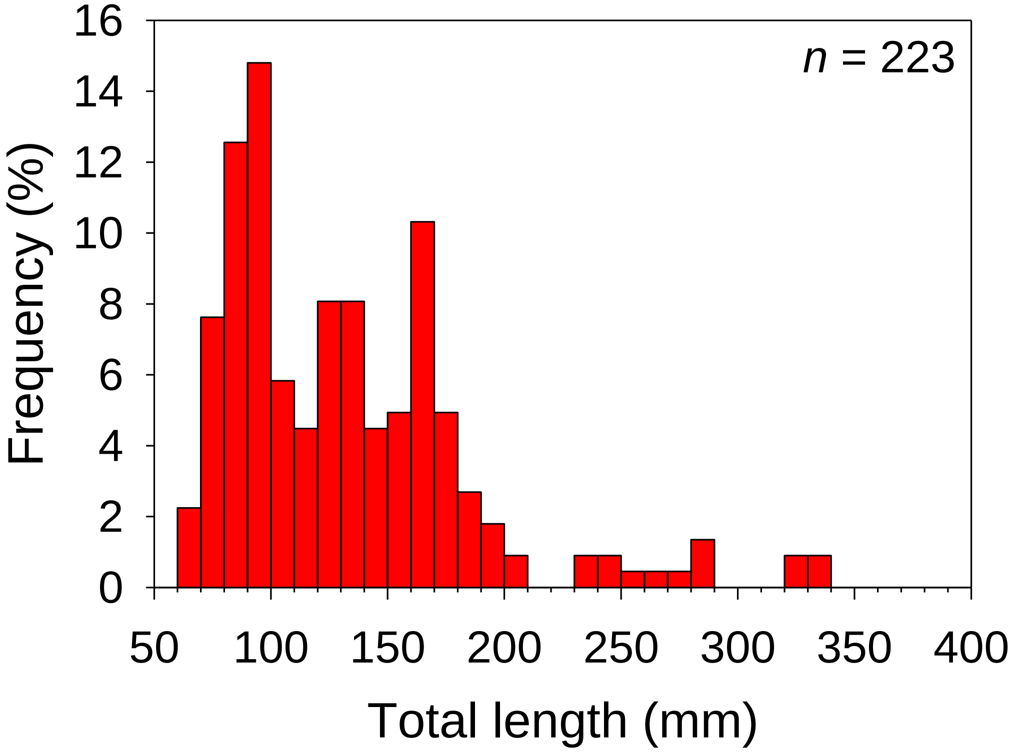

Figure 66. Length-frequency histogram of the Smallmouth Bass catch from electrofishing in Ririe Reservoir in 2018.

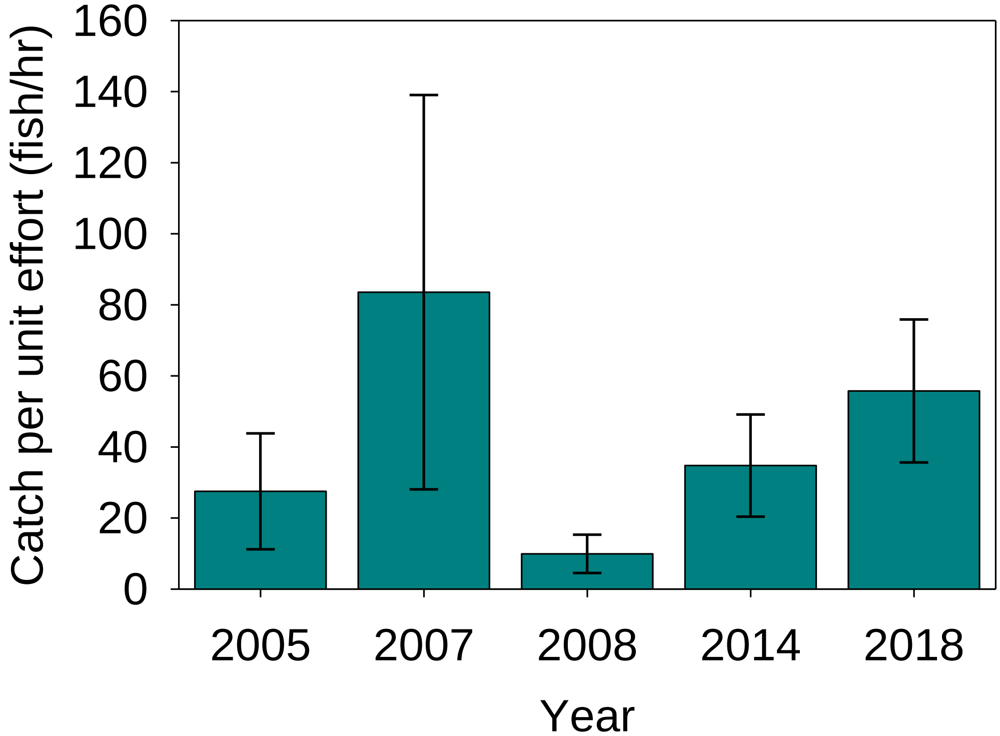

Figure 67. Catch-per-unit-effort (fish/hr) with 95% confidence intervals for Smallmouth Bass sampled with night boat electrofishing in Ririe Reservoir in 2005, 2007, 2008, 2014, and 2018.

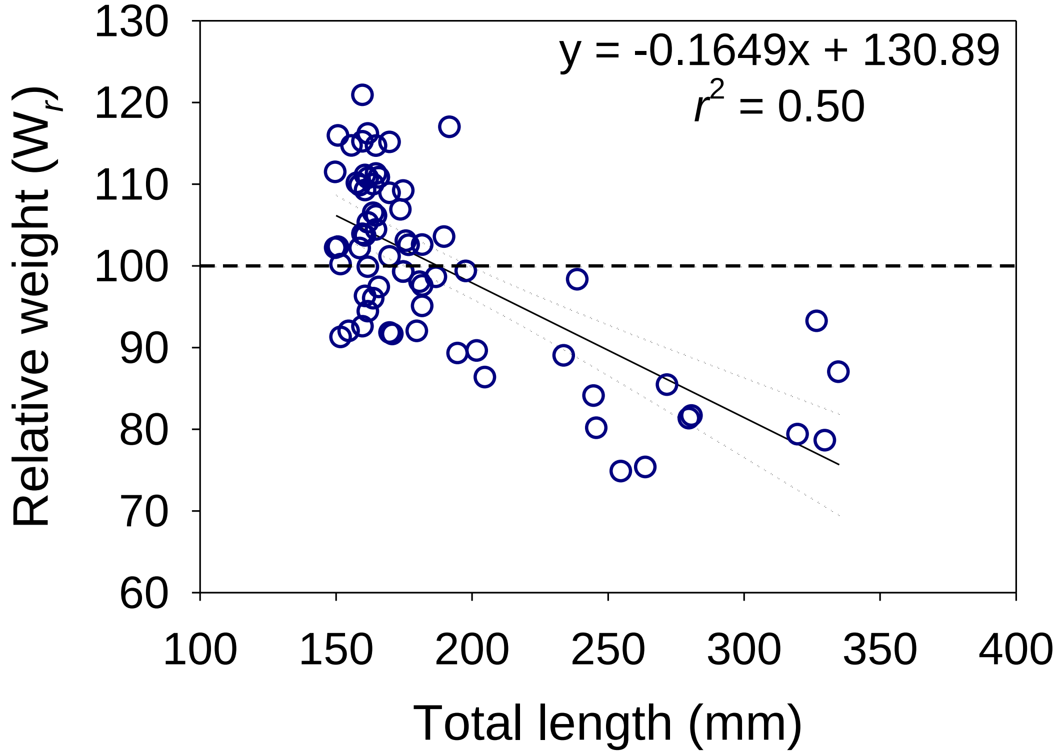

Figure 68. Relative weights by total length of Smallmouth Bass collected from shoreline boat electrofishing surveys in 2018.

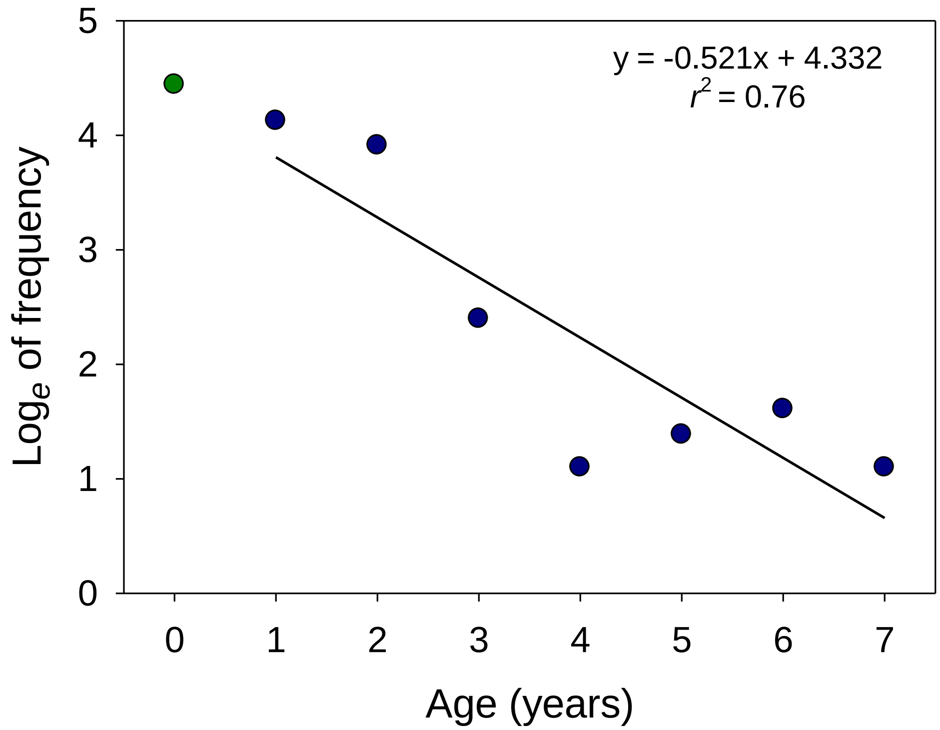

Figure 69. Catch curve for Smallmouth Bass sampled with boat electrofishing in Ririe Reservoir in 2018 Solid line represents the linear regression of the expected catch of Smallmouth Bass from ages 2 through 7 (blue circles). Age-0 (green circle) was excluded from the analysis.

ISLAND PARK RESERVOIR

ABSTRACT

We used suspended gill nets to assess the kokanee population in Island Park Reservoir during June 2018. We collected 1,053 fish in nine net-nights of effort. Overall relative abundance was comprised of Redside Shiner *Richardsonius balteatus* (35%), Utah Sucker *Catostomus ardens* (28%), kokanee *Oncorhynchus nerka* (17%), Utah Chub *Gila atraria* (11%), Rainbow Trout *Oncorhynchus mykiss* (7%), and Brook Trout *Salvelinus fontinalis* (<1%). Average gill net catch rates of kokanee were 20.1 per net night (±13.3). Rainbow Trout average gill-net catch was 8.6 per net night (± 2.9). The gill net catch rate for kokanee was greater than the 2017 gill net catch rate (4.77), but similar to the 2016 (18.2) and 2015 (14.0) estimates. Of the kokanee otoliths examined for thermal marks (*n* = 100), only 12% (*n* = 12) contained thermal marks indicative of hatchery-origin fish and the remaining 88% (*n* = 88) were wild (i.e. no thermal marks). Kokanee abundance remains relatively low in IPR compared to other regional waters surveyed in recent years, where gill net catch rates were 89 kokanee per net night (2018) for Ririe Reservoir and 55 kokanee per net night (2017) for Mackay Reservoir. Future fisheries management may attempt different stocking strategies (e.g. size, locations, and timing) while investigating the influence of annual variation in reservoir volume, climate, and water quality influence the fishery.

Authors:

Jenn Vincent
Regional Fisheries Biologist

Jon Flinders
Regional Fisheries Biologist

Brett High
Regional Fisheries Manager

INTRODUCTION

Island Park Reservoir (IPR) has been recognized as a quality recreational fishery since the early 1950s, supporting as much as 176,000 hours of angling effort annually, with angler catch rates averaging 0.68 fish per hour. Rainbow Trout *Oncorhynchus mykiss* (RBT) have provided the bulk of angler catch, with kokanee *O. nerka*, Brook Trout *Salvelinus fontinalis* (BKT), Mountain Whitefish *Prosopium williamsoni,* and Yellowstone Cutthroat Trout *O. clarkii bouvieri* (YCT) adding to the creel. Supplemental stockings have played a large role in the management of the fishery, which is primarily supported by hatchery releases of RBT and kokanee, although some spawning by both species occur in the Henrys Fork Snake River upstream of the reservoir. Annual RBT fingerling stockings have averaged 461,661 fish over the past 80 years and have been as high as 2.5 million fish in 1959 (Appendix F). Beginning in 2010, the Idaho Department of Fish and Game increased the size of fingerling RBT (> 6 inches) stocked in Island Park to reduce the potential for entrainment through the dam. Fingerling numbers were reduced to approximately 150,000 fish that accounted for the same biomass as the nearly 500,000 smaller fingerlings stocked in earlier years.

The history of kokanee stocking has varied considerably over the years (Appendix F). Nearly 120,000 kokanee were stocked into IPR in 1944-1945, followed by 144,000 stocked into Moose Creek in 1957. These initial stockings resulted in a self-sustaining population of kokanee, which spawned in Moose Creek. The Idaho Department of Fish and Game (IDFG) established a kokanee trapping facility on Moose Creek to collect eggs for stocking in other waters. The Moose Creek kokanee trap was operated intermittently between 1963 and 1975, with over 5 million eggs collected in 1969. Between 1976 and 1979, IPR was drawn down to near record levels on two occasions, and treated with rotenone during the 1979 draw down. The purpose of these rotenone treatments was to remove nongame fish species. Annual kokanee fry stocking of nearly 500,000 fish in 1981, 1982, and 1984 re-established the run, and trapping at Moose Creek resumed in 1987, though most fish were passed over the trap and allowed to spawn naturally. The trap was operated again in 1990 and 1991, but low numbers of fish were captured. Drought conditions and low populations prohibited trap operations from 1992-1994. In 1995, over 200,000 eggs were again collected at the Moose Creek trap, but future trap operations were ceased due to low returns combined with the identification of other, more easily obtained egg sources (e.g., Deadwood Reservoir). The trap was installed once again in 2003, but too few fish were captured to provide the necessary egg collection, so all fish were passed over the trap and allowed to spawn naturally. From 2009 to 2014 in an attempt to re-establish a kokanee spawning run, IDFG stocked an average of 61,618 fingering kokanee annually into both Moose Creek and at Big Springs on the Henrys Fork of the Snake River. In the reservoir itself, IDFG has stocked an average of just over 241,000 kokanee annually since 1990.

Historically, the proliferation of nongame fish, primarily Utah Chub *Gila atraria* and Utah Sucker *Catostomus ardens*, have been blamed for declines in the sport fishery in IPR. Several rotenone projects have been undertaken to reduce overall nongame fish abundance and improve angler catch rates. The efficacy of these treatments was questioned as early as 1982, when Ball et al. (1982) observed that the three chemical rehabilitations of IPR over the previous 25 years had not resulted in successful at permanent or long-term eradication of nongame species. Furthermore, improvements in the trout fishery appeared to be the result of increased stocking rates, especially noticeable with the mean annual introduction of 72,491 catchable RBT between 1980 and 1985. Ball et al. (1982) further noted that the observed declines in the RBT fishery two to four years after treatment were the result of decreased levels of hatchery inputs and were not due to increased Utah Chub and Utah Sucker densities. The most recent chemical treatment of the reservoir, conducted in 1992, yielded similar results, with catch rates not improving upon levels prior to the treatment (Gamblin et al. 2002). More recently, Garren et al. (2008) found that nongame fish exceed pre-rotenone treatment levels within five years following treatments and that angler catch rates within five years following rotenone treatments were not significantly different than angler catch rates prior to treatments, suggesting that rotenone treatments had no effect on improving angler catch rate in IPR.

Island Park Reservoir is operated as an irrigation storage reservoir for agricultural users downstream, and is, therefore, subject to fluctuations in annual water levels. Increases in reservoir storage normally begin at the close of irrigation season in October and last until demand for water increases, typically in late May or early June. Fall reservoir storage levels can fluctuate from the lowest storage level recorded of 270 acre-feet in 1992 to nearly 90% full (121,561 acre-feet), as seen in 1997. Recent analysis of reservoir storage indicates that reservoir carryover is positively related to gill-net catch rates for salmonids. A significant relationship between reservoir carryover and salmonid gill-net catch rate the following year by examining spring gill-net catch and the previous year's reservoir level has been documented (Garren et al. 2008). Years following low reservoir storage typically show a reduction in sport fish densities in gill nets the following year. Although the relationship between carryover and gill-net catch rates has been identified, it is unclear what mechanism is affecting salmonid populations. Possible mechanisms may be increased mortality due to lost habitat associated with drawdowns, entrainment through the dam due to increased outflow, and/or reduction in zooplankton forage base. A study focusing on factors regulating kokanee populations in a northern Idaho reservoir found kokanee population losses as high as 90% due to entrainment (Maiolie and Elam 1998). All age-classes of kokanee in this study were found near the dam during a netting survey making them susceptible to entrainment due to high volumes of water being released. Consistent with the observed decline in kokanee populations, Island Park Dam was modified in 1994 with a new intake structure to facilitate power generation as part of the Island Park Hydroelectric Project (Ecosystems Research Institute 1994), thereby altering the location of water withdrawals from the reservoir. Although both intake structures are located at the reservoir bottom, the hydroelectric intake is 206 m east of the pre-1994 intake structure and closer to the river channel. The hydroelectric facility is capable of handling up to 960 cubic feet per second (cfs). Therefore, throughout most of the year, the entire outflow is routed through the hydroelectric facility intake. To prevent entrainment, the hydroelectric intake structure features wedge wire screens with 9.5-mm openings. National Marine Fisheries Service (NMFS) screening criteria requires screen mesh with openings no larger than 2.4 mm to prevent passage of juvenile salmonids (NMFS 2011). Although this criteria is designed for anadromous fishes, it is the only reviewed criteria for juvenile salmonids and has been implemented in non-anadromous waters for screening juvenile salmonids. Additionally, the approach velocities near the hydroelectric intake are unknown, and blockage to any area of the screen could result in areas of increased velocity that could increase the likelihood of entrainment or impingement. Based on the current screen design, entrainment or impingement of juvenile kokanee is a possible source of mortality. Surveys of the Henrys Fork Snake River immediately below Island Park Dam have documented kokanee, indicating that some size classes are able to pass though the screened intake. Additionally, recent gillnetting in IPR (Schoby et al. 2010) found high gill-net catch rates of kokanee in the deep water in front of Island Park dam, in the proximity of the existing water intake structures.

Although drought, reservoir operation, and other environmental conditions may have impacted kokanee since the early 1990s, the alteration of intake facilities may be substantially inhibiting the re-establishment of the IPR kokanee fishery. In response to low kokanee angler catch rates, the potential impacts of entrainment, re-establish self-sustaining spawning runs, IDFG altered its stocking practices in 2009. Historically, juvenile kokanee were stocked directly into IPR between May and June, when inflow and outflow from the reservoir are increasing. This may contribute to the potential for entrainment as kokanee may actively follow river currents while migrating downstream (Fraley and Clancey 1988). Beginning in 2009, IDFG released half (approximately 125,000) of the annual kokanee stocking directly into IPR, with the remaining releases split between Big Springs Creek and Moose Creek (Figure 1). In-reservoir stockings occur throughout the reservoir, although the west end is the preferred location when it is accessible in the spring. Tributary releases are intended to reduce downstream migration through the reservoir, to allow fingerlings a chance to grow larger before encountering the intake structures, and to allow kokanee to imprint on tributaries to establish spawning runs in these locations.

STUDY AREA

Island Park Reservoir is located on the Henrys Fork Snake River 40-km north of Ashton, Idaho and 150-km upstream from the confluence with the South Fork Snake River (Figure 70). Island Park Dam is a 23-m high earth-fill rock-faced structure operated by the United States Bureau of Reclamation to provide water for irrigation in Fremont and Madison Counties. The drainage area upstream from the dam is 774 km^2, varying in elevation from 1,920 to 3,017 m. At gross pool capacity (143,430 acre feet), the reservoir covers 3,388 hectares and has a shoreline of about 97 km. Since first filling in 1939, the minimum storage was 270 acre-feet occurring in 1992. Runoff and numerous springs supply water to streams entering the reservoir. Maximum reservoir level or storage capacity generally occurs in May and June. Thereafter, gradual drawdown through the summer and fall lowers the reservoir to varying degrees, depending upon irrigation needs. Ice generally covers the reservoir from December to May.

OBJECTIVES

To obtain current information on the fish population, and to develop appropriate management recommendations to achieve management objectives states in the State Fish Management Plan.

METHODS

We targeted the kokanee population using experimental gill nets. Gill nets were set from June 18 to 21, 2018. Experimental gill nets measured 49-m long by 6-m deep with 16, 3-m long panels, which were randomly positioned in the net. The monofilament bar mesh measured 13, 19.25, 38, 52, 64, 76, and 102 mm with each mesh representing two panels. We set nets at dusk and retrieved them the following morning. Gill nets were deployed in the reservoir in areas with a maximum depth of 20 m and were set at the thermocline. We used a water quality meter (YSI Inc., Yellow Springs, Ohio) to take water temperature at the surface and every subsequent meter down the water column until the thermocline was identified by a several degree water temperature difference from the previous depth. Sites were randomly selected by overlaying a grid system (100 m × 100 m) using mapping software). We identified captured fish to species and recorded total lengths (TL; mm) and weights (g). We calculated relative abundance as well as catch per unit effort (CPUE; fish per net-night). Relative weights (W_r) were calculated by dividing the actual weight of each fish (in grams) by a standard weight (W_s) for the same length for that species multiplied by 100 (Anderson and Neumann 1996). We used the formula, log W_s = -4.898 + 2.990 log TL for RBT (Simpkins and Hubert 1996) and, log W_s = -5.062 + 3.033 log TL for kokanee (Milewski and Brown 1994).

We calculated proportional stock density (PSD) and relative stock density (RSD-400) to describe the size structure of trout populations in IPR. We calculated PSD for kokanee and RBT using the following equation:

$$\text{PSD} = \frac{\text{number} \geq 300 \text{ mm}}{\text{number} \geq 200 \text{ mm}} \times 100$$

We calculated RSD-400 for kokanee and RBT using the following equation:

$$\text{RSD-400} = \frac{\text{number} \geq 400 \text{ mm}}{\text{number} \geq 200 \text{ mm}} \times 100$$

Criteria used for PSD and RSD-400 values for kokanee and RBT populations were based on past calculations and kept consistent for comparison purposes. This methodology (and size designation) is used on other regional waters to provide comparison between lakes and reservoirs throughout the Upper Snake Region.

We examined all kokanee for sexual maturity and removed the sagittal otoliths. After removal, all otoliths were cleaned and stored in individually-labeled vials. Otoliths were used to estimate age and determine whether the fish was hatchery or wild origin. Since 1997, all kokanee eggs stored at Cabinet Gorge Fish Hatchery have been marked with thermal mass-marking techniques (Volk et al. 1990). Hatchery-origin kokanee had distinct thermal marks used to determine brood year. Otoliths were examined for thermal mars at IDFG Nampa Research aging lab Otoliths were examined with a compound microscope at 200- and 400-power magnification. Thermal marks were compared with reference samples taken from the hatchery during fry rearing to make brood year assignments. We conducted a visual assessment for spawning adult kokanee in Moose and Lucky Dog creeks on September 13, 2018 beginning at the mouth of Moose Creek and ending at the Forest Service road 292 crossing (~7 km in length).

RESULTS

We collected 1,053 fish in nine net-nights of effort (117 fish per net-night) using gill nets. Overall, relative abundance of the gill-net catch was dominated by Redside Shiner (35%), Utah Sucker (28%), and kokanee (17%); with Utah Chub (11%), RBT (7%), and BKT (<1%) composing a less abundant portion of the catch. Gill-net catch rate (CPUE) was highest for Redside shiner (41.3), followed by Utah Sucker (33.3), kokanee (20.1), RBT (8.7), and BKT (0.2; Figure 71). Kokanee CPUE was higher in 2018 compared to 2017, but similar to 2015 and 2016 (Figure 72). Kokanee ranged from 68 to 275 mm, with a mean length of 213 mm (± 3.7; Figure 73). Both the PSD and RSD-400 were 0 for kokanee. Mean relative weight of kokanee across all size classes was below the standard 100 at 88 (± 1.1; Table 26). Kokanee relative weights were similar across size classes (r^2 = 0.05; Figure 74).

Rainbow Trout ranged from 83 to 575 mm, with a mean length of 278 mm (± 18.7; Figure 75). The PSD was 50 and RSD-400 was 8 for RBT. Mean relative weight of RBT was 85 (± 3.0), which was below the standard 100 (Table 26). Relative weights of RBT were similar across size classes ($r^2 = 0.02$; Figure 76).

Of the 100 kokanee otoliths that were examined, 12% exhibited thermal marks and were identified as hatchery kokanee from spawn year 2016 (n = 2) and 2017 (n = 10). Wild-origin kokanee represented the remaining 88% (i.e. no thermal marks present). We were unable to fit a logistic regression model to size (TL) at sexual maturity due the absence of larger (> 300 mm) sexually mature kokanee in the nets. No adult spawning kokanee were detected from visual observations in Moose and Lucky Dog Creeks.

DISCUSSION

There was a two-fold increase in the total number of all fish species caught in the 2018 compared to 2017 gill-net survey suggesting a possible increase in the total fish population in IPR. In conjunction with the increase of total fish, kokanee gill-net catch rates have increased over the last four years in IPR and the kokanee gill-net catch rate for 2018 was a fourfold increase from 2017. Although we captured more kokanee in 2018, there was a stark difference in length-frequency distribution between 2017 and 2018. Over 88% of the kokanee captured in 2017 were age-0 kokanee (< 100 mm), while 95% of the captured kokanee in the 2018 survey were age-2 kokanee. The lack of age-0 kokanee in our 2018 survey was in part due to a shortage of kokanee eggs statewide in 2018 due to low run returns at the Deadwood Reservoir egg collection facility. The high prevalence of age-2 kokanee suggests high overwinter survival in 2016 and 2017. In addition, there was a high percentage of wild origin kokanee (88%) captured. A small number (n = 3) of these wild-origin kokanee were age-0 (< 150 mm) kokanee indicating wild production of kokanee is contributing to the population.

Although the total fish population of the reservoir has increased, both kokanee and RBT relative weights were below the standard 100 and lower than values observed in 2017. This is likely due to the increased fish density in the reservoir rather than limiting food resources as zooplankton abundance surveys were conducted on waters throughout the region in 2014 and high zooplankton densities were found in IPR (Flinders et al. 2016b). Although, more information is needed regarding the seasonal zooplankton abundance in IPR to fully understand this food source.

Kokanee gill net catch rates appear to be increasing in IPR, however, these gill net catch rates are still lower than those observed in other kokanee fisheries in the region, e.g., Mackay Reservoir and Ririe Reservoir (Flinders et al. 2016b). One factor that may be affecting the IPR kokanee population is fluctuations in reservoir water levels from year to year. Fall drawdowns of reservoirs have been found to result in the loss of kokanee spawning habitat and lead to reduced egg-to-fry survival (Maiolie et al. 2006). Furthermore, fall drawdowns may result in water temperature fluctuations, decrease or alter prey resources, decrease accessibility to macrophyte cover which indirectly alters predatory-prey interactions (Wilcox and Meeker 1992), and decrease accessibility to spawning/rearing tributaries (Carmignani and Roy 2017). As such, kokanee gill net catch rates were significantly lower in 2017 following a large fall reservoir drawdown in 2016. Gill net catch rates have now rebounded in 2018 after the 2017 fall reservoir pool retained over 82,000 acre-feet more water than 2016. This high reservoir winter carryover is a likely factor to the increased overwinter survival of kokanee. Large fluctuations in reservoir levels during the fall spawn and early winter may be playing a large factor influencing kokanee populations in IPR.

Retaining water in reservoirs across the region is important for fish health and survival in future years.

Evaluations of kokanee spawning in the tributaries of IPR, which have not been conducted since 2016, would also help IDFG to further quantify the wild contribution of kokanee in IPR. In 2016, a carcass survey was conducted on Henrys Lake Outlet, with 95% of the carcasses determined to be wild fish due to the lack of thermal marking on otoliths (IDFG in progress). In addition, eyed-eggs were planted in artificial redds from 2013 to 2015 in Moose and Lucky Dog creeks in an aim to re-establish a wild kokanee spawn in IPR. An updated spawning ground survey should be conducted to evaluate the hatchery vs. wild component of the IPR kokanee fishery.

Identifying limiting factors on kokanee in IPR is an objective in the Fisheries Management Plan (IDFG 2013). We believe that any number of indirect factors are at a threshold where even a slight change between favorable and unfavorable conditions exhibit effects on the kokanee population. Annual variability in reservoir volume, reservoir water conditions (e.g. temperature, dissolved oxygen, etc.), climatic variations (e.g. snowpack, air temperature, etc.), prey abundance, and the various interactions these variables have with one another may have indirect effects which result in large shifts in the IPR kokanee population. Fish managers need to continue analyzing potential direct methods used to analyze and bolster the kokanee population (i.e. varying stocking regimes, use of egg boxes) and begin focusing on how indirect water quality and climatic factors influence this population.

Current information quantifying angler harvest and angler catch rates of this fishery are not currently available. Our most recent 2013 creel survey indicated higher angler catch rates than any prior survey since 1980, but we do not know if this trend has continued. As such, a creel survey should be conducted and will help to direct future management actions.

MANAGEMENT RECOMMENDATIONS

1. Continue using gill nets on an annual basis to monitor the IPR kokanee fishery and on a triannual basis to monitor the entire IPR fishery.

2. Conduct kokanee visual spawner surveys in IPR tributaries to monitor trends in adult abundance and determine if past IDFG juvenile/eyed-egg releases in these locations have established spawning runs.

3. Continue using kokanee from the Henrys Lake Outlet or other acceptable sources to establish a spawning population in Moose Creek, either through adult releases or egg collection and incubation in Moose Creek.

4. Monitor seasonal trends in kokanee and Rainbow Trout prey resources through zooplankton and macroinvertebrate surveys.

5. Monitoring water quality parameters and reservoir levels in IPR and how these metrics relate to kokanee survival in the IP.

Table 27. Stock density indices ([PSD] = proportional stock density; [RSD] = relative stock density) and relative weights (W_r) for Rainbow Trout and kokanee collected using gill nets in Island Park Reservoir, 2018. Sample size (*n*) for relative weight values is noted in parentheses.

	Rainbow Trout (*n*)	kokanee (*n*)
PSD	50.0	0.0
RSD-400	7.8	0.0
RSD-500	3.1	--
W_r		
<200 mm	83.3 (12)	87.3 (23)
200 – 299 mm	87.8 (32)	88.3 (152)
300 – 399 mm	88.4 (27)	--
>399 mm	76.3 (5)	--
Mean	85.4	88.2

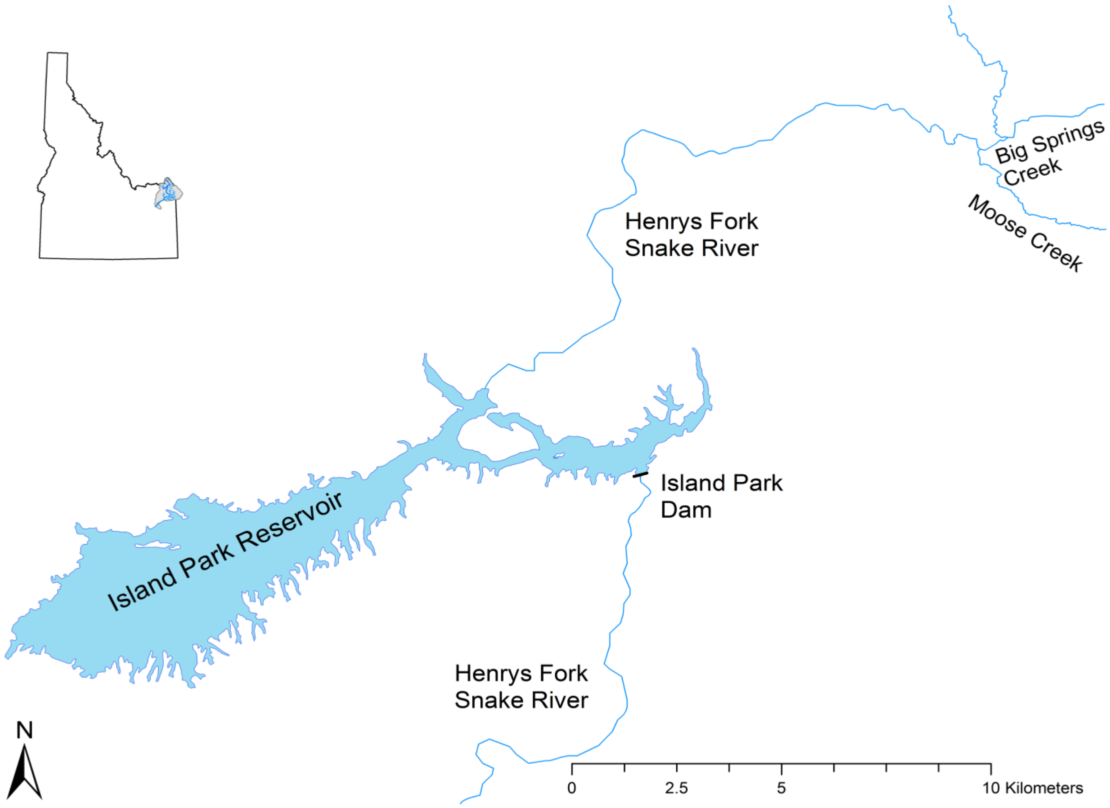

Figure 70. Map of Island Park Reservoir and the major tributaries in southeastern Idaho.

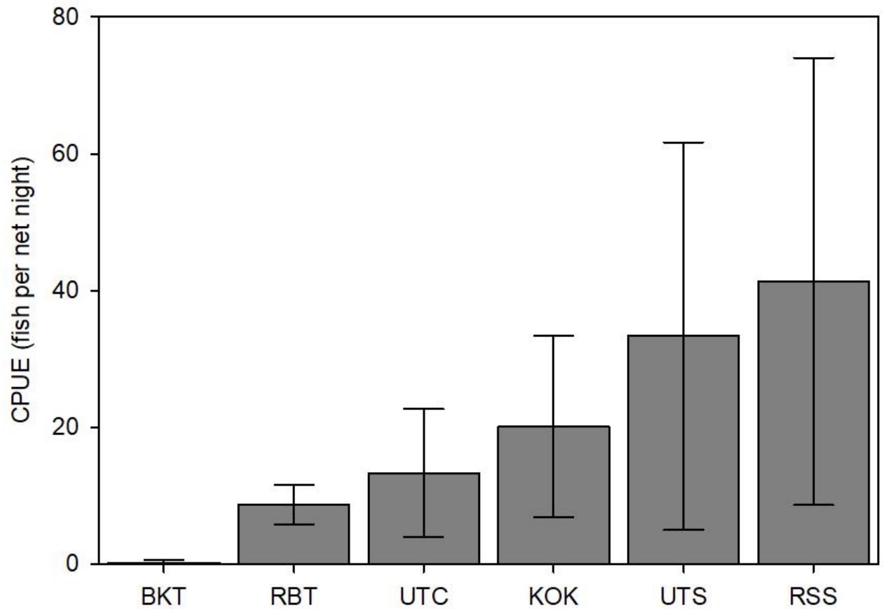

Figure 71. Catch per unit effort (CPUE; number of fish per net-night) and 95% confidence intervals for Brook Trout (BKT), Rainbow Trout (RBT), Utah Chub (UTC), kokanee (KOK), Utah Sucker (UTS), and Redside Shiner (RSS) collected using gill nets in Island Park Reservoir, 2018.

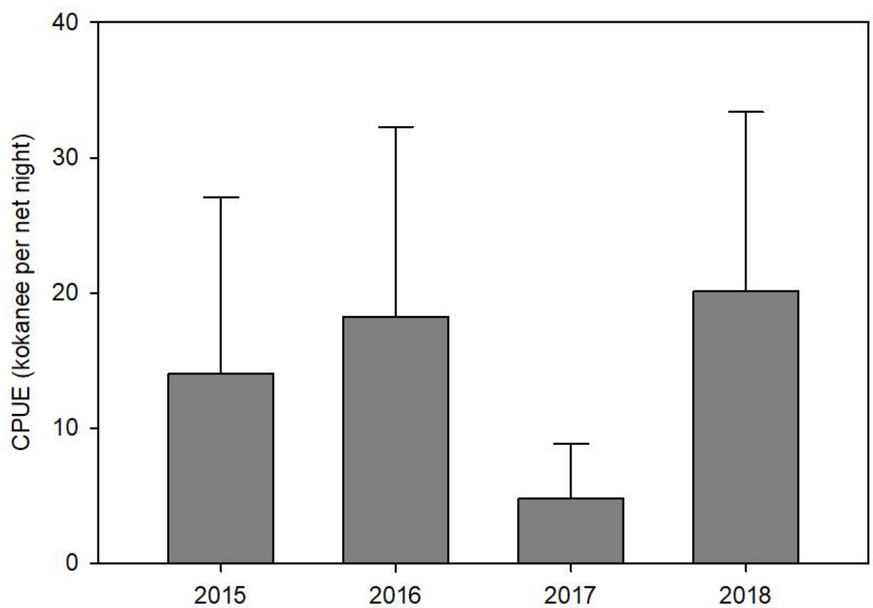

Figure 72. Kokanee gill-net catch per unit effort (CPUE) and 95% confidence intervals collected using gill nets in Island Park Reservoir from 2015 to 2018.

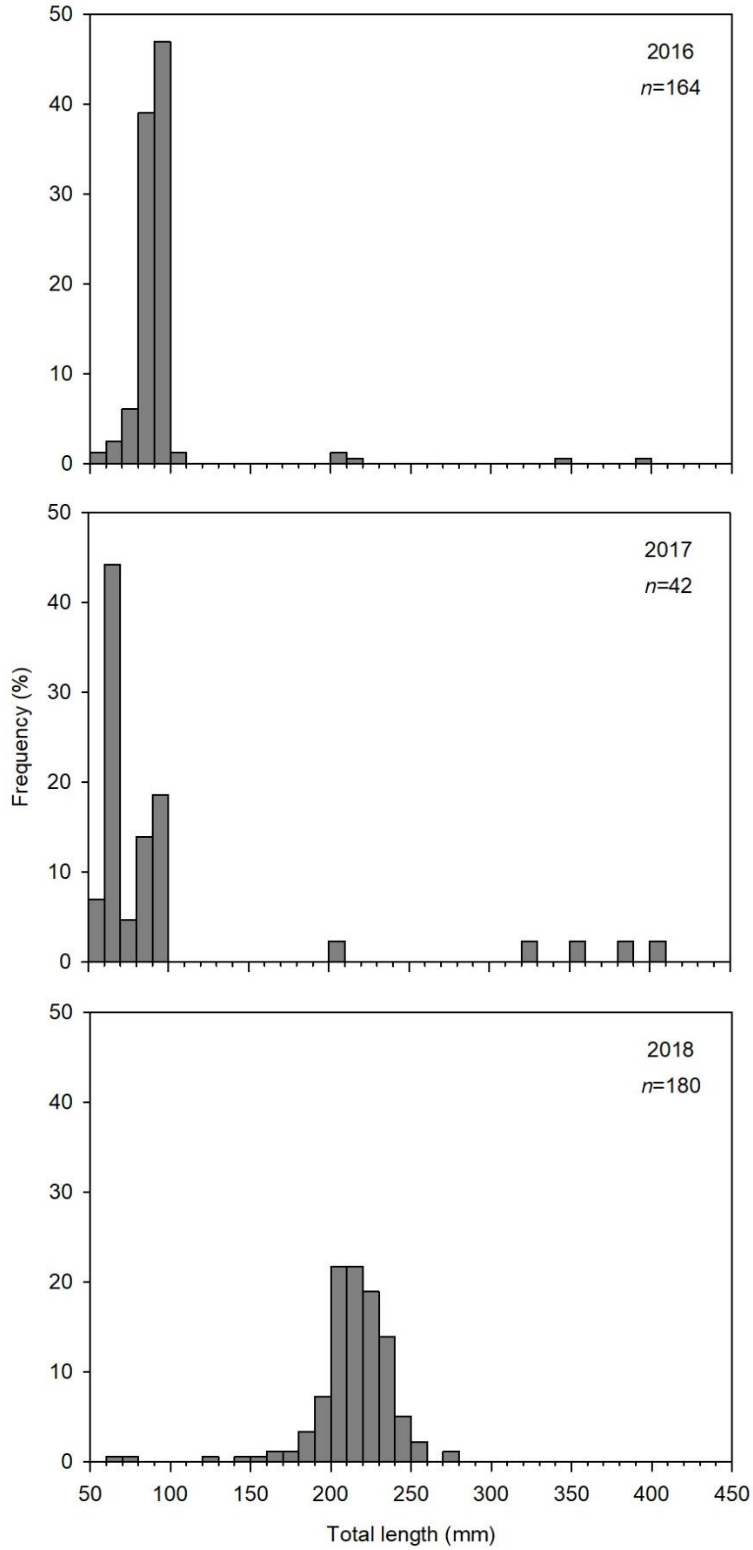

Figure 73. Length-frequency distribution (%) of kokanee captured using gill nets in Island Park Reservoir in 2016, 2017, and 2018.

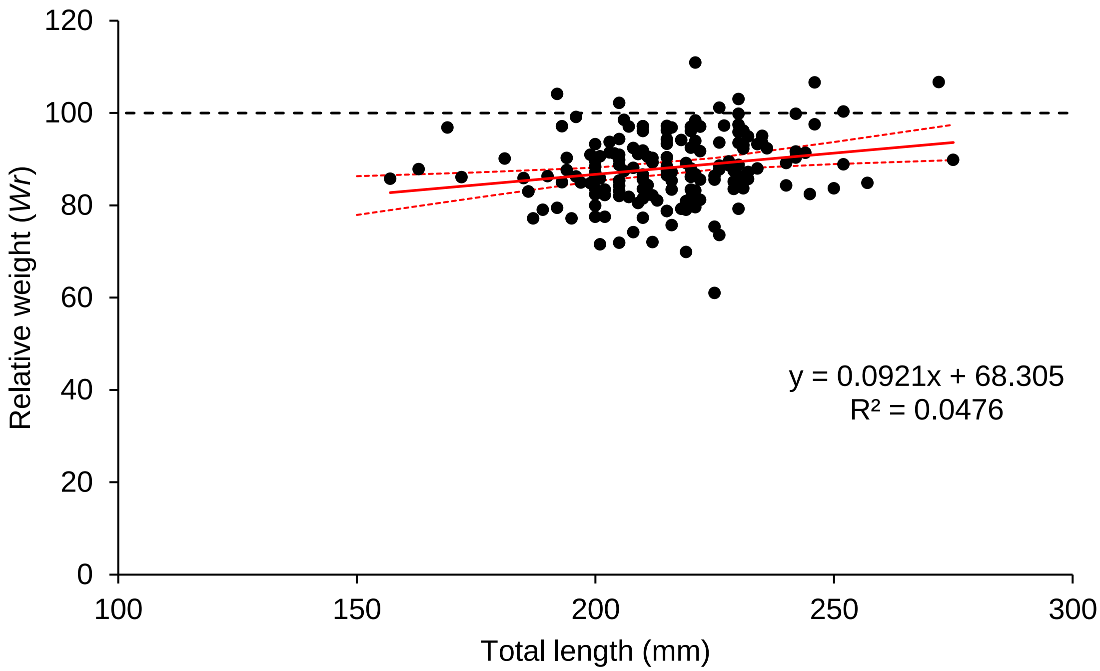

Figure 74. The relative weight (*Wr*) of kokanee across total length (mm) in Island Park Reservoir, 2018. The linear regression curve is represented by the solid red line and 95% confidence intervals are represented by the dotted red line.

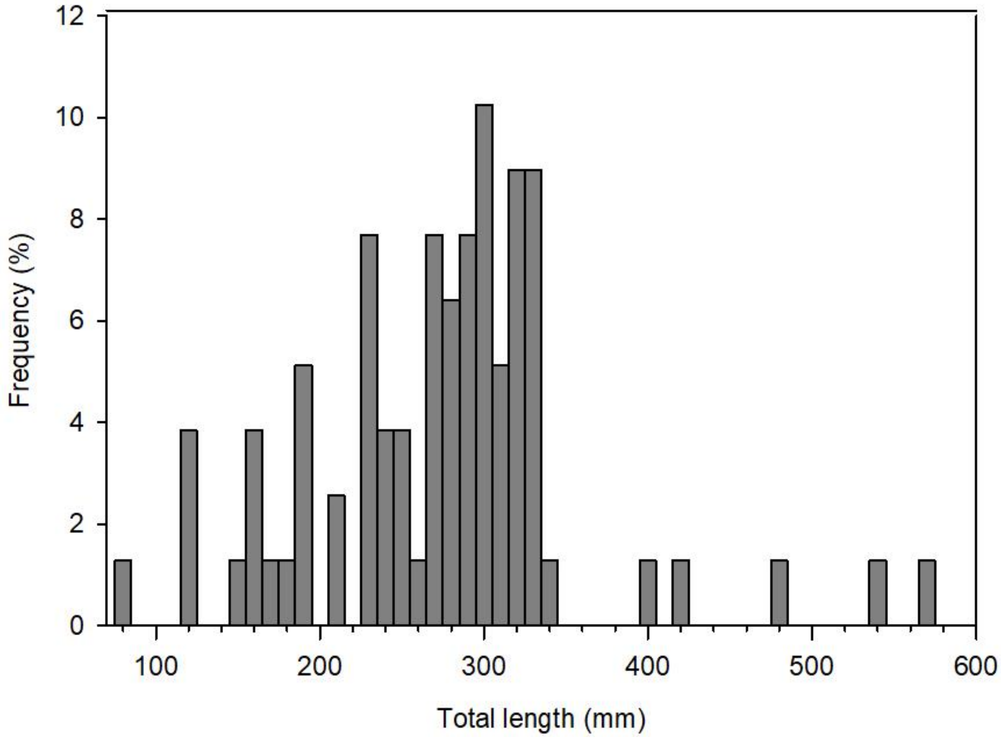

Figure 75. Length-frequency distribution (%) of Rainbow Trout captured using gills nets in Island Park Reservoir, 2018.

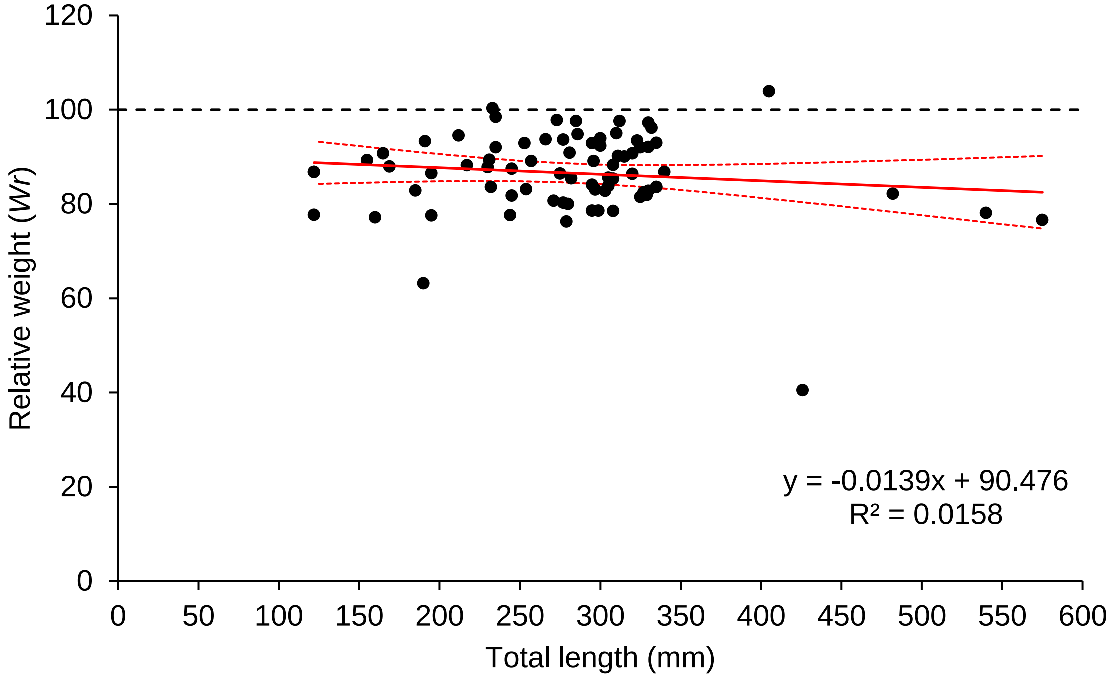

Figure 76. The relative weight (*Wr*) of Rainbow Trout across total length (mm) in Island Park Reservoir, 2018. The linear regression curve is represented by the solid red line and 95% confidence intervals are represented by the dotted red line.

Appendix F. Annual kokanee stocking in Island Park Reservoir, Moose Creek, and Big Springs Creek, 1944 – 2018.

	Island Park Reservoir		Moose Creek			Big Spring Creek	
Year	Fingerling	Fry	Fingerling	Fry	Eggs	Fingerling	Fry
1944	67,770	--	--	--	--	--	--
1945	51,510	--	--	--	--	--	--
1968	360,000	--	--	107,724	--	--	--
1969	200,000	--	--	--	--	--	--
1981	--	--	--	503,198	--	--	--
1982	--	--	--	199,800	--	--	--
1984	--	--	--	760,300	--	--	--
1985	833,690	--	--	--	--	--	--
1988	--	--	--	104,720	--	--	25,200
1989	--	--	--	233,020	--	--	--
1990	189,000	--	167,850	--	--	--	--
1991	104,745	--	20,000	135,660	--	--	--
1992	142,142	--	115,905	--	--	--	63,000
1993	200,624	--	--	--	--	--	--
1994	596,250	--	--	--	--	--	--
1995	500,000	--	--	--	--	--	--
1996	5,000	--	419,100	--	--	--	--
1997	554,315	--	--	--	--	--	--
1998	125,304	--	--	--	--	--	--
1999	41,600	--	304,807	--	--	--	--
2000	--	--	579,128	--	--	--	--
2001	474,640	--	--	--	--	--	--
2002	402,648	--	--	--	--	--	--
2003	30,000	--	--	--	--	--	--
2004	203,695	--	--	--	--	--	--
2005	248,000	--	--	--	--	--	--
2006	418,575	--	--	--	--	--	--
2007	620,760	--	--	--	--	--	--
2008	--	223,040	--	--	--	--	--
2009	125,875	--	62,938	--	--	62,938	--
2010	108,575	--	54,287	--	--	54,287	--
2011	54,515	--	59,955	--	--	59,955	--
2012	120,391	--	65,400	--	--	65,400	--
2013	125,000	--	62,500	--	--	62,500	--
2014	129,250	--	64,625	--	53,050a	64,625	--
2015	248,704	--	--	--	60,000b	--	--
2016	252,340	--	--	--	--	--	--

	Island Park Reservoir		Moose Creek			Big Spring Creek	
Year	Fingerling	Fry	Fingerling	Fry	Eggs	Fingerling	Fry
2017	250,349						
2018[c]	--						

[a]Includes 9,929 eggs stocked in Lucky Dog Creek. [b]Includes 10,000 eggs stocked in Lucky Dog Creek.
[c]Due to the shortage of kokanee eggs statewide no kokanee were stocked.

LITERATURE CITED

Anderson, R. O. 1980. Proportional stock density (PSD) and relative weight (*Wr*): interpretive indices for fish populations and communities. Pages 27-33 *in* S. Gloss and B. Shupp, editors. Practical fisheries management: more with less in the 1980’s. American Fisheries Society, New York Chapter, Ithaca, New York.

Anderson, R. O., and R. M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447-482 *in* B.R. Murphy and D. W. Willis, ed. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Barica, J., and J. A. Mathias. 1979. Oxygen depletion and winterkill risk in small prairie lakes under extended ice cover. Journal of Fisheries Research Board of Canada 36: 980-986.

Ball, K., V. Moore, and J. Curran. 1982. Regional Fishery Management Investigations, Job Performance Report, Project F-71-R-6. Idaho Department of Fish and Game, Boise.

Bertalanffy, L. 1957. Quantitative laws in metabolism and growth. The Quarterly Review of Biology 32: 217-231.

Brown, R. S., W. A. Hubert, and S. F. Daly. 2011. A primer on winter, ice, and fish: what fisheries biologists should know about winter ice processes and stream-dwelling fish. Fisheries 36:8-26.

Bureau of Reclamation, 2001. Ririe Reservoir Resource Management Plan. U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Snake River Area Office, Boise, Idaho.

Campbell, N. A. 1990. Biology, vol. 2. How populations evolve. The Benjamin/Cummings Publishing Company, Inc. Redwood City, California.

Carmignani, J. R. and A. H. Roy. 2017. Ecological impacts of winter water level drawdowns on lake littoral zones: a review. Aquatic Sciences 79:803-824.

Coon, J. C. 1978. Lake and reservoir investigations. Federal aid to fish and wildlife restoration 1978 Annual Performance Report program F-53-R-12. Idaho Department of Fish and Game, Boise, Idaho.

Corsi, C. 1989. Regional Fisheries Management Investigations, 1986 Region 6 (Idaho Falls), Volume 076, Article 07. Idaho Department of Fish and Game, Boise.

DeVita, E. L. 2014. Modeling population interactions between native Yellowstone Cutthroat Trout and invasive Rainbow Trout in the South Fork Snake River. Master’s Thesis. Humbolt State University. Arcata, California.

Dibble, K. L., C. B. Yackulic, T. Kennedy, and P. Budy. 2015. Flow management and fish density regulate salmonid recruitment and adult size in tailwaters across western North America. Ecological Applications 25:2168–2179.

Dillon, J. 1996. Smallmouth bass growth in Idaho – statewide perspective. Fisheries Research Brief, Idaho Department of Fish and Game, No. 96-01.

Dumont, H. J., I. Vandevelde, and S. Dumont. 1975. Dry weight estimate of biomass in a selection of Cladocera, Copepoda and Rotifera from plankton, periphyton and benthos of continental waters. Oecologia 19: 75-97.

Ecosystems Research Institute. 1994. Operations and procedures plan maintenance and mitigation Island Park hydroelectric project, FERC No. 2973.

Elle, S. 1997. Wild Trout Investigations. Report #97-38. Idaho Department of Fish and Game, Boise.

Fausch, K. D., Y Taniguchi, S. Nakano, G. D. Grossman, and C. R. Townsend. 2001. Flood disturbance regimes influence rainbow trout invasion success among five Holarctic regions. Ecological Applications 11:1438-1455.

Flinders, J. M. 2012. Stable isotope analysis ($\delta^{15}N$ and $\delta^{13}C$) and bioenergetics modeling of spatial-temporal foraging patterns and consumption dynamics in brown and Rainbow Trout populations within catch-and-release areas of Arkansas tailwaters. Dissertation, University of Arkansas, Fayetteville.

Flinders, J., D. Keen, B. High, and D. Garren. 2016a. Idaho Fish and Game fishery management annual report, Upper Snake Region 2014. Idaho Department of Fish and Game Report #16-108. Boise, Idaho.

Flinders, J., B. High, D. Keen, and D. Garren. 2016b. Fishery management annual report, Upper Snake Region, 2015. Report No. 16-111. Idaho Department of Fish and Game, Boise, Idaho.

Fraley, J. J., and P. T. Clancey. 1988. Downstream migration of stained kokanee fry in the Flathead River system, Montana. Northwest Science 62(3):111-117.

Frankham, R. 1995. Inbreeding and Extinction: A threshold effect. Conservation Biology 9:792-799.

Gamblin, M., T. J. Herron, B. A. Rich, and W. C. Schrader. 2002. Regional Fisheries Management Investigations, Upper Snake Region. 1994 Job Performance Report, Program F-71-R-19. Idaho Department of Fish and Game, Boise.

Garren, D., W. C. Schrader, D. Keen, and J. Fredericks. 2006a. Regional fisheries management investigations. 2003 Annual Performance Report, Project F-71-R-28. Report #04-25. Idaho Department of Fish and Game, Boise.

Garren, D., W. C. Schrader, D. Keen, and J. Fredericks. 2006b. Fishery management annual report, 2005 Upper Snake Region. Report #06-38. Idaho Department of Fish and Game, Boise.

Garren, D., W. C. Schrader, D. Keen, and J. Fredericks. 2008. Fishery management annual report, Upper Snake Region 2006. Report No. 08-102. Idaho Department of Fish and Game, Boise, Idaho.

Garren, D., J. Fredericks, and D. Keen. 2009. Fishery management annual report, 2007 Upper Snake Region. Report #09-111. Idaho Department of Fish and Game, Boise.

Gregory, J. 2018. Big Lost River drainage fish ladder function assessment. Report for the U. S. Fish and Wildlife Service, Chubbuck, Idaho.

Griffith, J. S. 1993. Coldwater streams. Pages 405-425 *in* C. C. Kohler and W. A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society. Bethesda, Maryland.

Grunder, S. A., T. J. McArthur, S. Clark, and V. K. Moore. 2008. Idaho Department of Fish and Game 2003 Economic Survey Report. Report #08-129. Idaho Department of Fish and Game, Boise.

Hauer, F. R., M. S. Lorang, D. Whited, and P. Matson. 2004. Ecologically Based Systems Management (EBSM), The Snake River – Palisades Dam to Henrys Fork. Final Report to the US Bureau of Reclamation, Boise, Idaho. Flathead Lake Biological Station, Division of Biological Sciences, The University of Montana, Polson, Montana. pp. 133.

Henderson, R., J. L. Kershner, and C. A. Toline. 2000. Timing and location of spawning by nonnative wild Rainbow Trout and native Cutthroat Trout in the South Fork Snake River, Idaho, with implications for hybridization. North American Journal of Fisheries Management 20:584-596.

High, B., G. Schoby, D. Keen, and D. Garren. 2011. Idaho Fish and Game fishery management annual report Upper Snake Region 2009. Idaho Department of Fish and Game Report #11-107. Boise, Idaho.

High, B., D. Garren, G. Schoby, and J. Buelow. 2015. Fishery management report, Upper Snake Region 2013. Report #15-108. Idaho Department of Fish and Game, Boise.

Hyatt, M. W., and W. A. Hubert. 2001. Proposed standard-weight equations for brook trout. North American Journal of Fisheries Management 21: 253-254.

IDFG. 2001. 2001-2006 Fisheries Management Plan. Idaho Department of Fish and Game, Boise, Idaho.

Idaho Department of Fish and Game (IDFG). 2007. Mountain Whitefish Conservation and Management Plan for the Big Lost River Drainage, Idaho.

IDFG. *In press.* 2011 Angler Economic Survey. Idaho Department of Fish and Game, Boise.

Idaho Department of Fish and Game. 2012. Standard fish sampling protocol for lowland lakes and reservoirs in Idaho. Report No. 12-10. Idaho Department of Fish and Game, Boise.

Idaho Department of Fish and Game. 2013. Fisheries management plan. 2013 – 2018. Boise, ID.

Isermann, D. A., and Knight, C. T. 2005. A computer program for age-length keys incorporating age assignment to individual fish. North American Journal of Fisheries Management 25:1153–1160.

Jackson, A. L., R. Inger, A. C. Parnell, and S. Bearhop. 2011. Comparing isotopic niche widths among and within communities: SIBER – Stable Isotope Bayesian Ellipses. Journal of Animal Ecology 80: 595-602.

Jackson M. C., I. Donohue, A. L. Jackson, J. R. Britton, D. M. Harper, and J. Grey. 2012. Population-level metrics of trophic structure based on stable isotopes and their application to invasion ecology. PLos One 7(2): e31757.

Jaeger, M. E., A. V. Zale, T. E. McMahon, and B. J. Schmitz. 2005. Seasonal movements, habitat use, aggregation, exploitation, and entrainment of saugers in the Lower Yellowstone River: an empirical assessment of factors affecting population recovery. North American Journal of Fisheries Management 25:1550-1568.

Johnson J. B, and M. C. Belk. 2006. What the status of Utah Chub tells us about conserving common, widespread species. American Fisheries Society Symposium 53: 165-173.

Kennedy, P. A. 2009. The effect of irrigation diversions on the Mountain Whitefish (*Prosopium williamsoni*) population in the Big Lost River. Master's thesis. Utah State University, Logan, Utah.

Korman, J., M. D. Yard, and T. Kennedy. 2017. Trends in Rainbow Trout recruitment, abundance, survival, and growth during a boom-and-bust cycle in a tailwater fishery. Transactions of the American Fisheries Society. 146:1043–1057.

Kruse, C. G. and W. A. Hubert. 1997. Proposed standard weight (W_s) equations for interior Cutthroat Trout. North American Journal of Fisheries Management 17:784-790.

Larson, E. I., K. A. Meyer, and B. High. 2014. Incidence of spinal injuries in migratory Yellowstone cutthroat trout captured at electric and waterfall-velocity weirs. Fisheries Management and Ecology 21:509-514.

Layman, C. A., D. A. Arrington, C. G. Montana, and D. M. Post. 2007. Can stable isotope ratios provide for community-wide measures of trophic structure? Ecology 88: 42-48.

Maceina, M. J., and P. W. Bettoli. 1998. Variating in Largemouth Bass recruitment in four mainstream impoundments of the Tennessee River. North American Journal of Fisheries Management 18: 998-1003.

Maiolie, M., and S. Elam. 1998. Kokanee entrainment losses at Dworshak Reservoir; Dworshak Dam Impacts Assessment and Fisheries Investigation Project. 1996 Annual Report, Project No. 198709900. Bonneville Power Administration, Portland, Oregon.

Maiolie, M. S., Bassista T. P., Peterson M. P., Harryman W., Arment W. J., and M. A. Duclos. 2006. Lake Pend Oreille fishery recovery project, project progress report, 2004 annual report 06-25. Idaho Department of Fish and Game. Boise, Idaho.

McFadden, J. T. and E. L. Cooper. 1962. An ecological comparison of six populations of Brown Trout (*Salmo trutta*). Transactions of the American Fisheries Society 91:53-62.

Meyer, K. A. and J. S. Griffith. 1997. First-winter survival of rainbow trout and brook trout in the Henrys Fork of the Snake River, Idaho. Canadian Journal of Zoology 75:59-63.

Meyer, K. A. and J. A. Lamansky, Jr. 2004. Assessment of native salmonids above Hells Canyon Dam, Idaho. Annual Progress Report 2003. Idaho Department of Fish and Game Report #04-26. Boise, Idaho.

Meyer, K. A., D. J. Schill, J. A. Lamansky, Jr., M. R. Campbell, and C. C. Kozfkay. 2006. Status of Yellowstone Cutthroat Trout in Idaho. Transactions of the American Fisheries Society 135:1329-1347.

Meyer, K. A., F. S. Elle., and J. A. Lamansky Jr. 2009. Environmental factors related to the distribution, abundance, and life history characteristics of Mountain Whitefish in Idaho. North American Journal of Fisheries Management 29:753–767.

Meyer, K. A., F. S. Elle, J. A. Lamansky, Jr., E. R. J. M. Mamer, and A. E. Butts. 2012. A reward-recovery study to estimate tagged-fish reporting rates by Idaho anglers. North American Journal of Fisheries Management 32:696-703.

Meyer, K. A. and D. J. Schill. 2014. Use of a statewide angler reporting system to estimate rates of exploitation and total mortality for Idaho sport fisheries. North American Journal of Fisheries Management 34:1145-1158.

Meyer, K. A., P. Kennedy, B. High, and M. Campbell. 2017. Purifying a Yellowstone Cuthroat Trout Stream by removing Rainbow Trout and hybrids via electrofishing. Transactions of the American Fisheries Society 146:1193-1203.

Milewski, C. L. and M. L. Brown. 1994. Proposed standard weight (*Ws*) equation and length-categorization standards for stream-dwelling brown trout (*Salmo trutta*). Journal of Freshwater Ecology 9:111-116.

Mitro, M.G. 1999. Sampling and analysis techniques and their applications for estimating recruitment of juvenile rainbow trout in the Henrys Fork of the Snake River, Idaho. PhD thesis, Montana State University, Bozeman.

Mitro, M. G., A. V. Zale, and B. A. Rich. 2003. The relation between age-0 Rainbow Trout (Oncorhynchus mykiss) abundance and winter discharge in a regulated river. Canadian Journal of Fisheries and Aquatic Sciences 60:135-139.

Moller, S., and R. Van Kirk. 2003. Hydrologic alteration and its effect on trout recruitment in the South Fork Snake River. Project Completion Report for Idaho Department of Fish and Game, Idaho State University, Pocatello.

Montana Department of Fish, Wildlife, and Parks. 1997. Mark recapture for Windows, version 5.0. Montana Department of Fish, Wildlife, and Parks, Helena.

Moore, V. and D. Schill. 1984. Federal aid in fish restoration: River and stream investigations-South Fork Snake River fisheries investigations. Job Completion Report F-73-R-5. Idaho Department of Fish and Game. Boise, Idaho.

NMFS (National Marine Fisheries Service). 2011. Anadromous salmonid passage facility design. NMFS, Northwest Region, Portland, Oregon.

Neumann, R. M., C. S. Guy, and D. W. Willis. 2012. Length, weight, and associated indices. In Zale, A. V., D. L. Parrish, and T. M Sutton, editors, Fisheries Techniques, Third Edition, chapter 14, pages 637-676. American Fisheries Society, Bethesda, MD.

Northcote, T. G., and G. L. Ennis. 1994. Mountain Whitefish biology and habitat use in relation to compensation and improvement possibilities. Reviews in Fisheries Science 2(4):347–371.

Parnell, A. C., R. Inger, S. Bearhop, and A. L. Jackson. 2010. Source partitioning using stable isotopes: coping with too much variation. PLoS One 5: e9672.

Pender, D. R. and T. J. Kwak. 2002. Factors influencing Brown Trout reproductive success in Ozark tailwater rivers. Transactions of the American Fisheries Society 131:698–717.

Pollock, K. H., C. M. Jones, and T. L. Brown. 1994. Angler survey methods and their applications in fisheries management. American Fisheries Society Special Publication 25.

Pollock, K. H., J. M. Hoenig, W. W. Hearn, and B. Calingaert. 2001. Tag reporting rate estimation: 1. An evaluation of the high-reward tagging method. North American Journal of Fisheries Management 21:521-532.

Rogers, L. E., W. T. Hinds, and R. L. Buschbom. 1976. General weight versus length relationship for insects. Annals of the Entomological Society of America 69:387-389.

Rogers, K. B., L. C. Bergsted, and E. E. Bergersen. 1996. Management Briefs: Standard weight equation for Mountain Whitefish. North American Journal of Fisheries Management 16:207-209.

Scheaffer, R. L., W. Mendenhall, and L. Ott. 1996. Elementary survey sampling, 5th edition. Duxbury Press. Belmont, California.

Schrader, W. C., and J. Fredericks. 2006a. South Fork Snake River investigations. 2003 Annual Job Performance Report 06-20. Idaho Department of Fish and Game. Boise.

Schrader, W. C., and J. Fredericks. 2006b. South Fork Snake River investigations. 2005 Annual Job Performance Report 06-50. Idaho Department of Fish and Game. Boise.

Schoby, G., B. High, D. Keen, and D. Garren. 2010. Fishery Management Annual Report, Upper Snake Region 2008. Report No. 10-107. Idaho Department of Fish and Game, Boise.

Schoby, G., B. High, D. Garren, and J. Fry. 2013. Fishery management annual report, Upper Snake Region 2009. Idaho Department of Fish and Game Report #13-117. Boise, Idaho.

Schoby, G., B. High, D. Keen, and D. Garren. 2014. Fishery management annual report, Upper Snake Region 2010. Idaho Department of Fish and Game Report #14-101. Boise, Idaho.

Schisler, G. J. 2010. Effects of whirling disease (*Myxobolus cerebralis*) exposure on juvenile Mountain Whitefish (*Prosopium williamsoni*). Colorado Division of Wildlife, Aquatic Research Section, Fort Collins.

Simpkins, D. G. and W. A. Hubert. 1996. Proposed revision of the standard-weight equation for Rainbow Trout. Journal of Freshwater Ecology 11:319-325.

Su, Z., and D. Clapp. 2013. Evaluation of sample designs and estimation methods for Great Lakes angler surveys. Transactions of the American Fisheries Society 142:234-246.

Thurow, R. F. and J. G. King. 1994. Attributes of Yellowstone Cutthroat Trout redds in a tributary of the Snake River, Idaho. Transactions of the American Fisheries Society 123:37-50.

Van Kirk, R. W., and M. Gamblin. 2000. History of fisheries management in the upper Henry's Fork watershed. Intermountain Journal of Sciences 6: 263-284.

Varley, J. D. and R. E. Gresswell. 1988. Ecologoy, status, and management of the Yellowstone cutthroat trout. American Fisheries Society Symposium 4:13-24.

Volk, E. C., S. L. Schroder, and K. L. Fresh. 1990. Inducement of unique otolith branding patterns as a practical means to mass-mark juvenile Pacific Salmon. American Fisheries Society Symposium 7:203-215.

Waters, A. W., D. M. Holzer, J. R. Faulkner, C. D. Warren, P. D. Murphy, and M. M. McClure. 2012. Quantifying cumulative entrainment effects for Chinook Salmon in a heavily irrigated watershed. Transactions of the American Fisheries Society 123:1180-1190.

Weiland, M. A., and R. S. Hayward. 1997. Cause for the decline of large rainbow trout in a tailwater fishery: Too much putting or too much taking? Transactions of the American Fisheries Society 126: 758-773.

Whiteley, A. R., P. Spruell, and F. W. Allendorf. 2006. Can common species provide valuable information for conservation? Molecular ecology 15:2767-2786.

Wilcox, D. A. and J. E. Meeker. 1992. Implications for faunal habitat related to altered macrophyte structure in regulated lakes in northern Minnesota. Wetlands 12:192–203.

Prepared By:	**Approved By:** IDAHO DEPARTMENT OF FISH AND GAME
John Heckel Regional Fisheries Biologist	Joseph R. Kozfkay State Fishery Manager
Jennifer Vincent Regional Fisheries Biologist	J. Lance Hebdon Chief of Fisheries
Jon Flinders Regional Fisheries Biologist	
Brett High Regional Fisheries Manager	